RS JPO Interoperability Profiles (IOPs) 101

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Robotic Systems Joint Project Office (RS JPO)

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14. ABSTRACT
Defines hardware & software interface requirements for UGVs Establishes the 1st baseline for UGV interoperability requirements V0 only addresses capabilities that are already fielded (albeit not fielded in a modular, interoperable fashion) Addresses point-to-point interoperability & modularity requirements UGV platforms UGV payloads (sensors, emitters, actuators) UGV radios UGV controllers Primarily based upon the Joint Architecture for Unmanned Systems (JAUS) (SAE AS-4)

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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

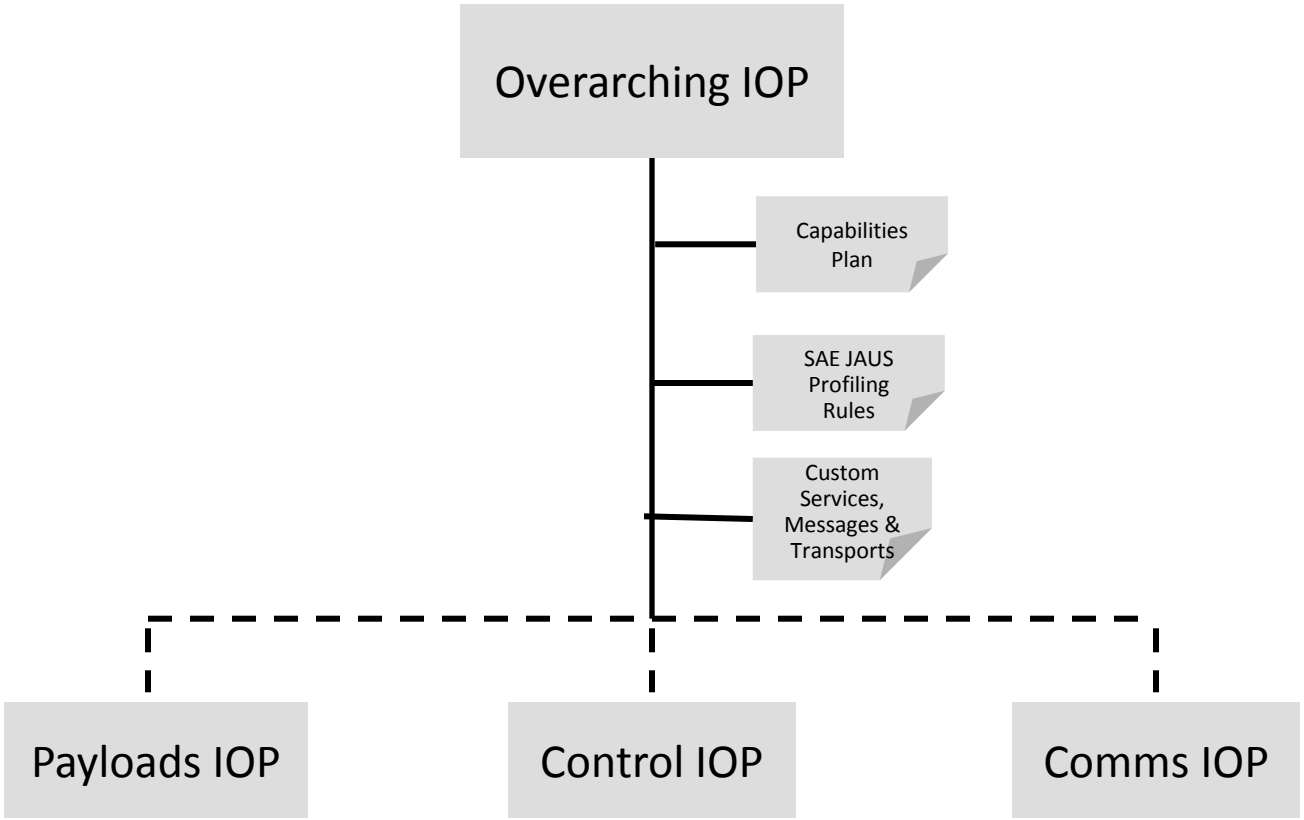
RS JPO UGV IOPs 101

- UGV IOP – What is it?
- IOP V0 – What does it mandate?
- UGV IOP – How does the Government use it?
- UGV IOP– How should industry use it?
- Additional Frequently Asked Questions
- Caveats & Managing Non-Compliant Interfaces

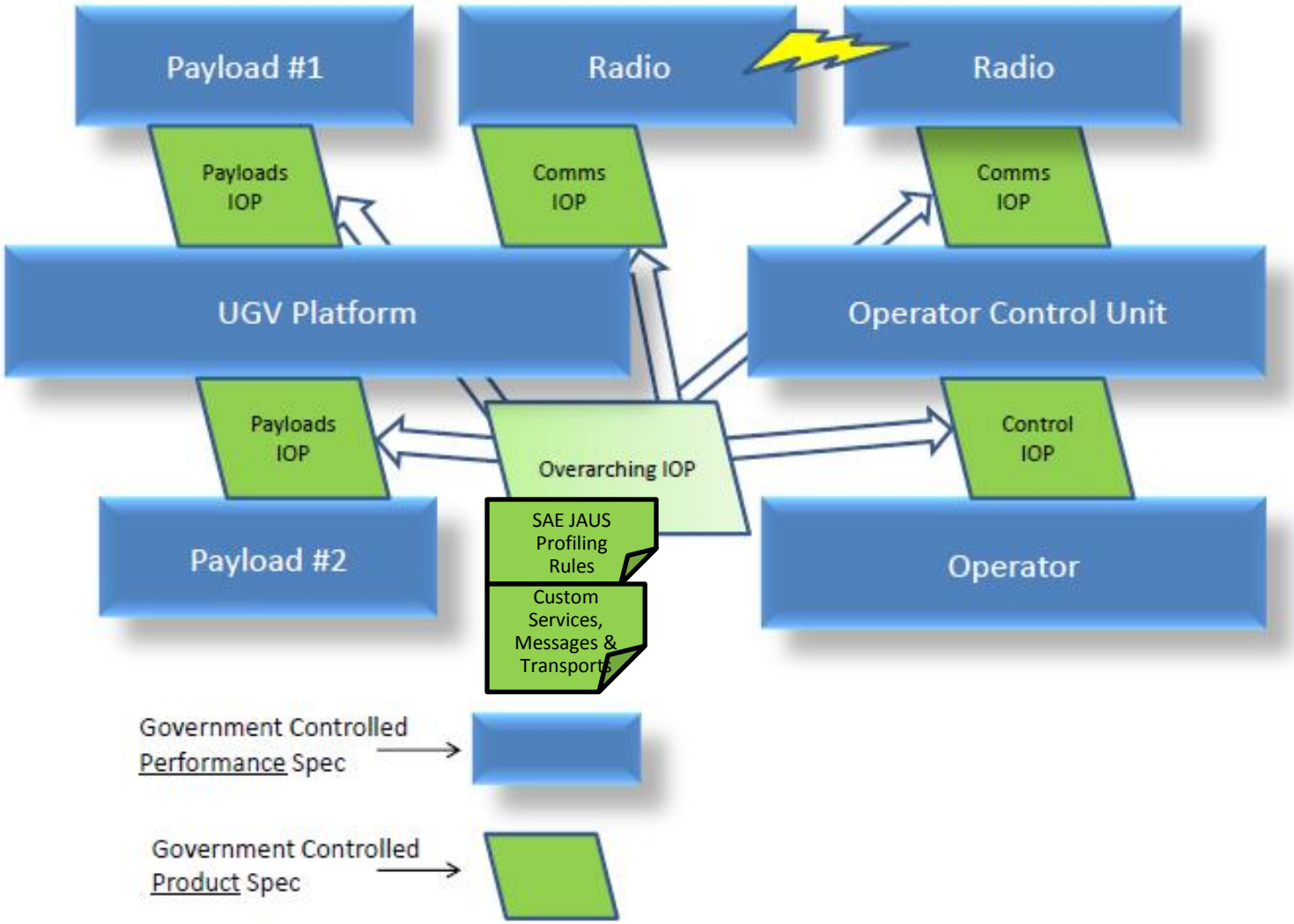
IOP V0 – What is it?

- Defines hardware & software interface requirements for UGVs
- Establishes the 1st baseline for UGV interoperability requirements
  - V0 only addresses capabilities that are already fielded (albeit not fielded in a modular, interoperable fashion)
  - Addresses point-to-point interoperability & modularity requirements
    - » UGV platforms
    - » UGV payloads (sensors, emitters, actuators)
    - » UGV radios
    - » UGV controllers
- Primarily based upon the Joint Architecture for Unmanned Systems (JAUS) (SAE AS-4)

IOP Structure

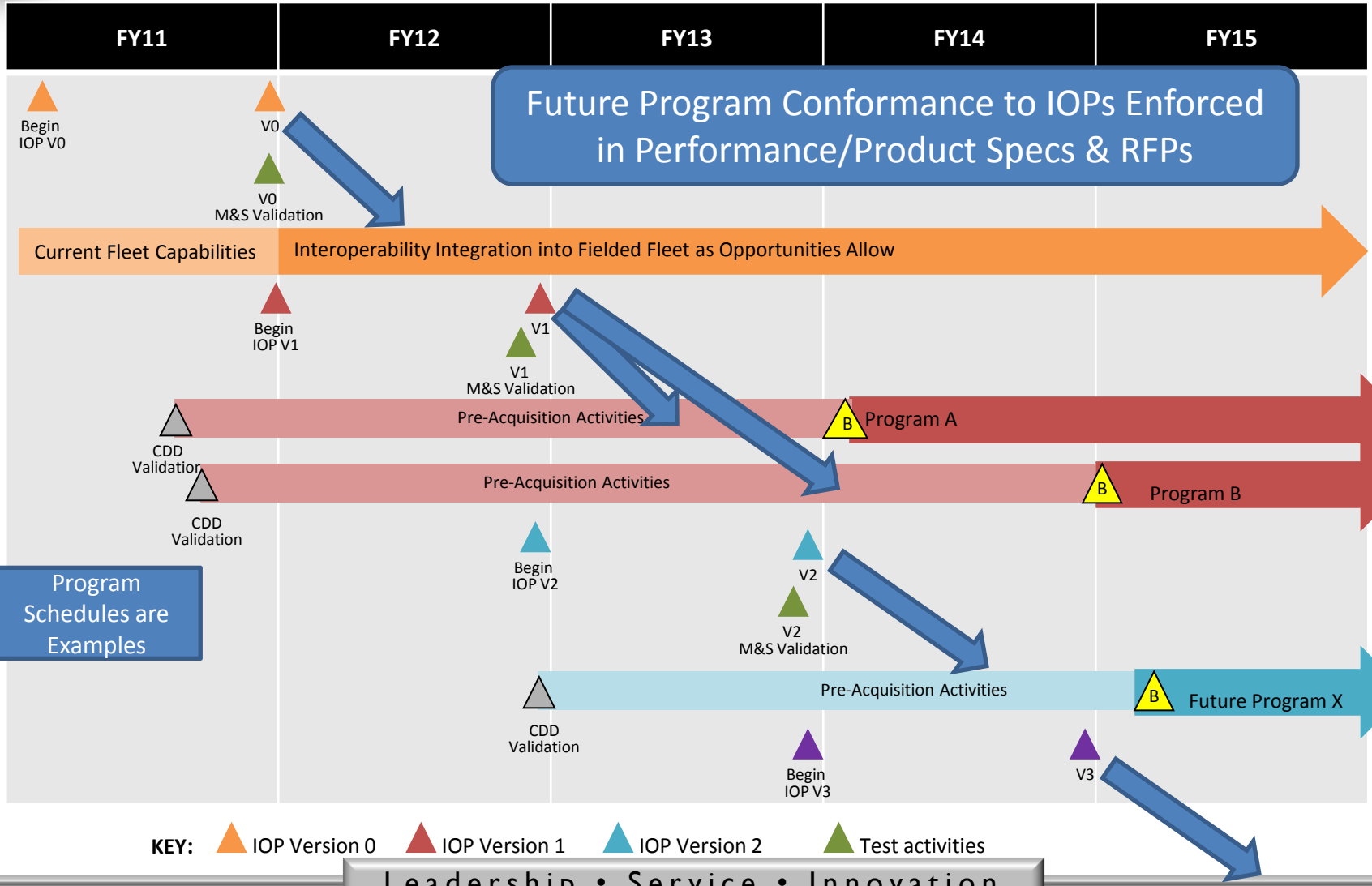


IOP Relation to Typical UGV Architecture



IOP Relationship to UGV Programs

ROBOTIC SYSTEMS JPO

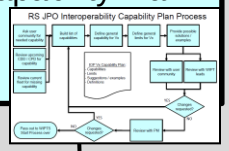


Annual Interoperability Profile (IOP) Version X (Vx) Development Process

ROBOTIC SYSTEMS JPO

Conduct Vx Mission Analysis

Develop Vx Capability Plan



Define Expected IOP Deliverables

Identify Alternative Candidate Standards for Each Capability

1Q

Conduct Trade Studies on Candidate Standards

Select Appropriate Standards

Identify Alternative Detailed Requirements

- Physical Interfaces
- Specific Messages
- Transport Protocols
- Network Requirements (i.e., addressing, etc.)

2Q

Conduct Trade Studies on Detailed Requirements

Select Detailed Requirements
(or define new requirements if not already defined in any standard)

Document Selected Standards & Requirements in IOP

3Q

Staff IOP Through WIPTs for Comment

Brief IOP to Interoperability Executive Board

Obtain Executive Board Approval of IOP

Publish IOP

PORs

4Q

RS JPO UGV IOPs 101

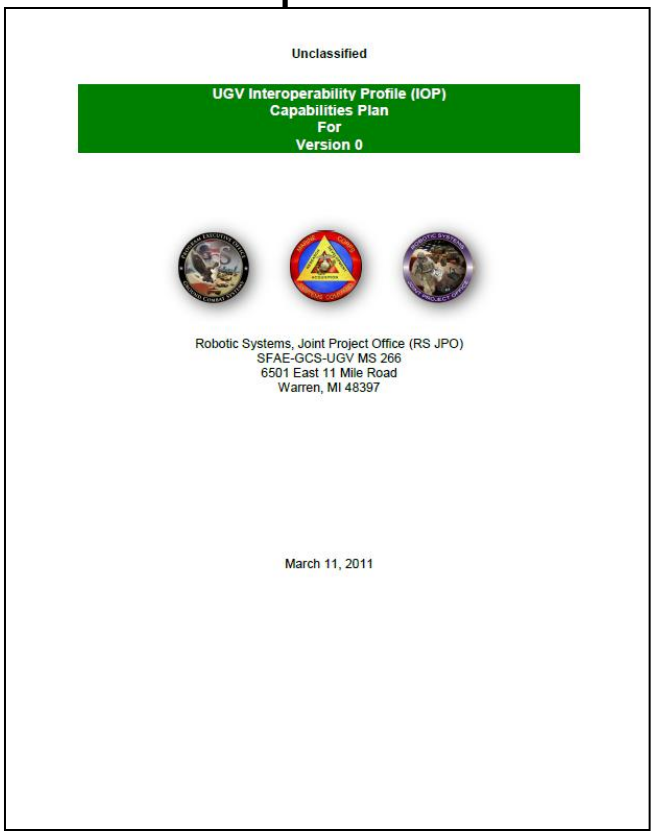
- UGV IOP – What is it?
- **IOP V0 – What does it mandate?**
- UGV IOP – How does the Government use it?
- UGV IOP – How should industry use it?
- Additional Frequently Asked Questions
- Caveats & Managing Non-Compliant Interfaces

IOP V0 – What does it mandate? (top level summary)

- Mandates that if a system is going include “Capability X”, then the corresponding IOP requirements for “Capability X” will be adhered to
- Mandates the use of Ethernet networking protocol
- Mandates software message formats for messages within scope
- Mandates 2 alternative physical connectors
  - For platforms, payloads and radios
- Mandates 2 alternative payload power values
- Mandates 2 alternative IP address management techniques
- Mandates Common Control Link (CCL) design constraints
- Recommends Warfighter/Machine Interface (WMI) design practices

IOP V0 Content – V0 Capabilities Plan

- V0 Capabilities Plan was developed March 2011
- Scopes & bounds what IOP V0 will define
- Focused on foundational capabilities inherent in currently fielded systems



Unclassified

UGV Interoperability Profile (IOP)
Capabilities Plan
For
Version 0

Robotic Systems, Joint Project Office (RS JPO)
SFAE-GCS-UGV MS 266
6501 East 11 Mile Road
Warren, MI 48397

March 11, 2011

IOP V0 Foundational Concept – "Interoperability Attributes"

- Every interoperability requirement will not be applicable to every system
- IOP provides a mechanism to independently specify these requirements in a composable manner, using Interoperability Attributes.
- Interoperability Attributes applicable to the specification and design of a system can be identified and utilized to filter applicable requirements from the UGV IOP, supporting system design, development, conformance and validation testing, initial operational test and evaluation, and fielding.

Example: Interoperability Attributes from Overarching IOP

Attribute	Paragraph	Title	Values
UGV Class	1.3.2	UGV Classes	Soldier Transportable, Vehicle Transportable, Self Transportable, Appliqué Package
Platform Databus	5.2.2	Databus	None, Ethernet
Transport	5.6.1.3	Transport	UDP, TCP, Custom
Platform Management	5.6.2	Platform Management & Platform Modes	None, Basic, Advanced
Mobility	5.6.3	Mobility	Remote Control, Teleoperation, Basic Navigation

Interoperability Attribute Example

Attribute	Paragraph	Title	Values
UGV Class	1.3.2	UGV Classes	Soldier Transportable, Vehicle Transportable, Self Transportable, Appliqué Package
Platform Databus	5.2.2	Databus	None, Ethernet
Transport	5.6.1.3	Transport	UDP, TCP, Custom
Platform Management	5.6.2	Platform Management & Platform Modes	None, Basic, Advanced
Mobility	5.6.3	Mobility	Remote Control, Teleoperation, Basic Navigation

Requirement applies when Basic Platform Management is selected for a given system.

[OVA 011] Robotic systems (controllers and/or vehicles) implementing the "Basic" Platform Management Interoperability Attribute shall do so by implementing the Platform Manager JAUS Node in accordance with the Basic Platform Management requirements specified in Section 4.2.1.1 of the *UGV IOP SAE JAUS Profiling Rules*.

Table 4.2-2: Component and Service Requirements for Basic Platform Manager

Basic Platform Manager Component	
Service	**Reference**
urn:jaus:jss:core:Discovery, v1.0	AS5710 JAUS Core Service Set
urn:jaus:jss:core:Liveness, v1.0	AS5710 JAUS Core Service Set
urn:jaus:jss:ugv:PowerPlantManager, v0.1	AS6091 JAUS UGV Service Set
urn:jaus:jss:ugv:Odometry, v0.1	AS6091 JAUS UGV Service Set
urn:jaus:iop:platformmanager:PlatformMode, v1.0	Custom Services, Messages, and Transports
urn:jaus:iop:platformmanager:HealthMonitor, v1.0	Custom Services, Messages, and Transports
urn:jaus:iop:platformmanager:PresetPose, v1.0	Custom Services, Messages, and Transports

The JAUS Profiling Rules documents mandates that these JAUS services must be included in the system. Additional guidance on implementation & interpretation of the services is also provided in the document.

Additional detail on this particular example provided later in presentation.

IOP V0 Content – Overarching IOP

- Provides the base concepts, architecture, requirements, and overview for the UGV IOP
- Specifically addresses platform, payload, mobility, on-vehicle network, communication, and messaging requirements. Introduces and presents the conformance and validation approach to be employed within the IOP.

Attribute	Paragraph	Title	Values
UGV Class	1.3.2	UGV Classes	Soldier Transportable, Vehicle Transportable, Self Transportable, Appliqué Package
Platform Databus	5.2.2	Databus	None, Ethernet
Transport	5.6.1.3	Transport	UDP, TCP, Custom
Platform Management	5.6.2	Platform Management & Platform Modes	None, Basic, Advanced
Mobility	5.6.3	Mobility	Remote Control, Teleoperation, Basic Navigation

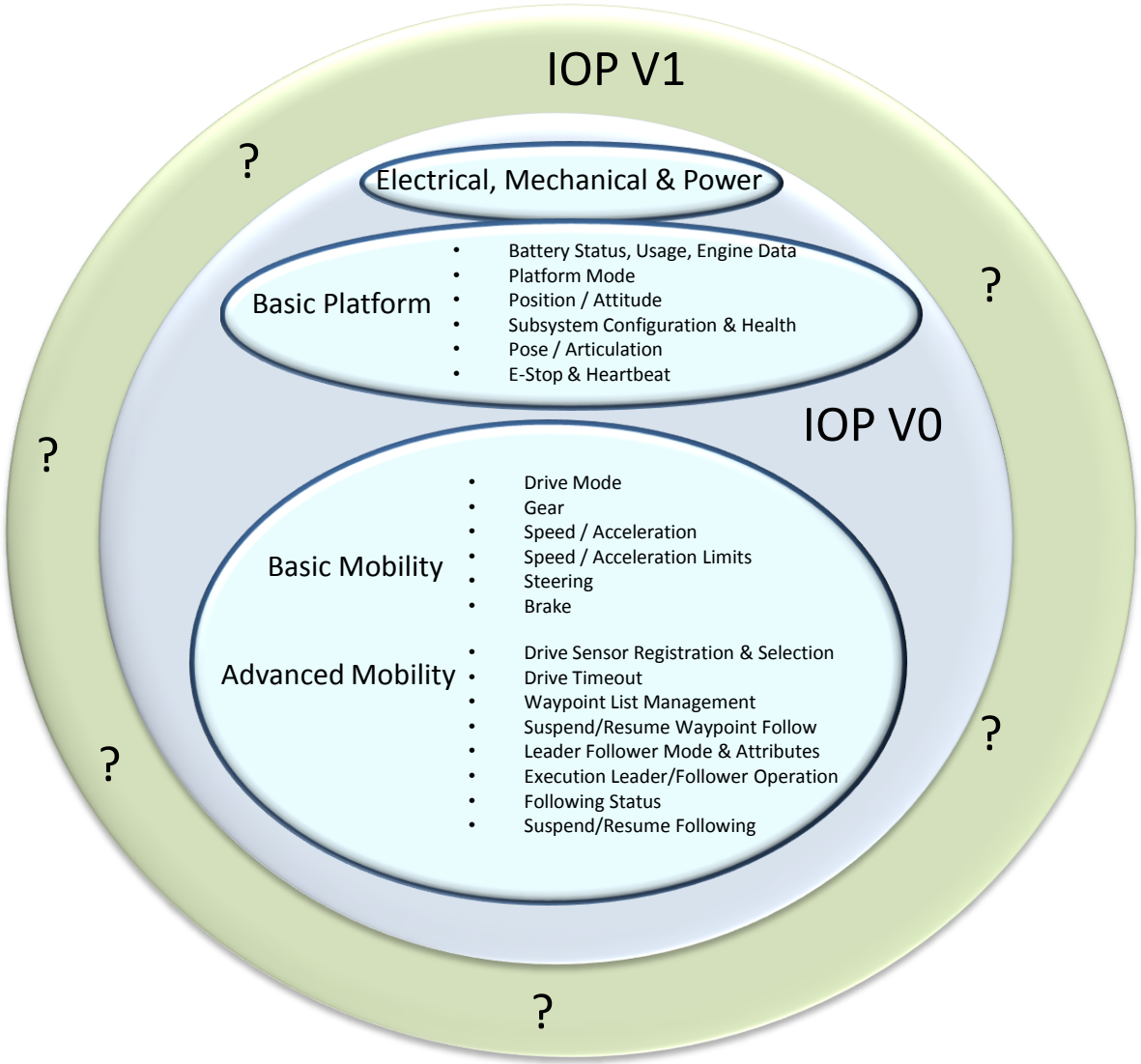
Example requirement associated w/ this Interoperability Attribute Value

[OVA 011] Robotic systems (controllers and/or vehicles) implementing the "Basic" Platform Management Interoperability Attribute shall do so by implementing the Platform Manager JAUS Node in accordance with the Basic Platform Management requirements specified in Section 4.2.1.1 of the *UGV IOP SAE JAUS Profiling Rules*.

4.3 Usage of Overarching IOP

The Overarching IOP will be used by the MATDEV and industry to serve as a description of the intent of the full IOP package, to describe its usage, to define overarching requirements for all systems, to point to applicable sections in the other IOPs, and to define Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

IOP V0 Scope – Overarching IOP



IOP V0 – What does it mandate? (Overarching IOP – 1 of 3)

ROBOTIC SYSTEMS JPO

General

[OVA 001] Robotic systems (vehicles) with a designated "Ethernet" Platform Databus Interoperability Attribute shall provide an on-board Gigabit Ethernet databus IAW IEEE 802.3-2008 for the integration of components and payload subsystems.

[OVA 002] The UGV platform shall supply power to all base configuration payloads.

[OVA 003] Payloads shall be implemented in accordance with the *UGV IOP Payloads Profile* and any required (specified) Interoperability Attributes.

[OVA 004] UGV platforms shall implement the communications data link interface in accordance with the *UGV IOP Communications Profile* and any required (specified) Interoperability Attributes.

[OVA 005] Command, control and status messages shall be implemented using the SAE AS-4 JAUS standards as profiled by the *UGV IOP SAE JAUS Profiling Rules* and any required (specified) Interoperability Attributes.

[OVA 006] Custom command, control and status messages shall be implemented in accordance with the *RS JPO, UGV IOP Custom Services, Messages and Transports*.

IOP V0 – What does it mandate? (Overarching IOP – 2 of 3)

ROBOTIC SYSTEMS JPO

Transport

[OVA 007] Robotic systems (controllers and/or vehicles) with a designated "JUDP" Transport Interoperability Attribute Value shall implement the transport in compliance with the JUDP transport specified in SAE JAUS AS5669A.

[OVA 008] Robotic systems (controllers and/or vehicles) with a designated "JTCP" Transport Interoperability Attribute Value shall implement the transport in compliance with the JTCP transport specified in SAE JAUS AS5669A.

[OVA 009] Robotic systems (controllers and/or vehicles) with a designated "Custom" Transport Interoperability Attribute Value shall implement the transport in compliance with the designated Custom transport specified in *UGV IOP Custom Services, Messages and Transports*.

Platform Management

[OVA 010] Robotic systems (controllers and/or vehicles) with a Platform Management Interoperability Attribute Value of "None" shall do so in accordance with the requirements specified in the *UGV IOP SAE JAUS Profiling Rules*.

[OVA 011] Robotic systems (controllers and/or vehicles) implementing the "Basic" Platform Management Interoperability Attribute shall do so by implementing the Platform Manager JAUS Node in accordance with the Basic Platform Management requirements specified in Section 4.2.1.1 of the *UGV IOP SAE JAUS Profiling Rules*.

[OVA 012] Robotic systems (controllers and/or vehicles) implementing "Advanced" Platform Management Interoperability Attribute shall do so by implementing the Platform Manager JAUS Node in accordance with the Advanced Platform Management requirements specified in the *UGV IOP SAE JAUS Profiling Rules*.

IOP V0 – What does it mandate? (Overarching IOP – 3 of 3)

Mobility

[OVA 013] Robotic systems (controllers and/or vehicles) implementing the "Remote Control" Value of the Mobility Interoperability Attribute shall do so by implementing the appropriate JAUS services in accordance with the definition and rules specified in Section 4.3.4 of the *UGV IOP SAE JAUS Profiling Rules*.

[OVA 014] Robotic systems (controllers and/or vehicles) implementing the "Teleoperation" Value of the Mobility Interoperability Attribute shall do so by implementing the appropriate JAUS services in accordance with the definition and rules specified in Section 4.3.5 of the *UGV IOP SAE JAUS Profiling Rules*.

[OVA 015] Robotic systems (controllers and/or vehicles) implementing the "Basic Navigation" Value of the Mobility Interoperability Attribute shall do in accordance with Section 4.3.6 of the *UGV IOP SAE JAUS Profiling Rules*.

Control

[OVA 016] Controller requirements shall be implemented in accordance with the *UGV IOP Control Profile*.

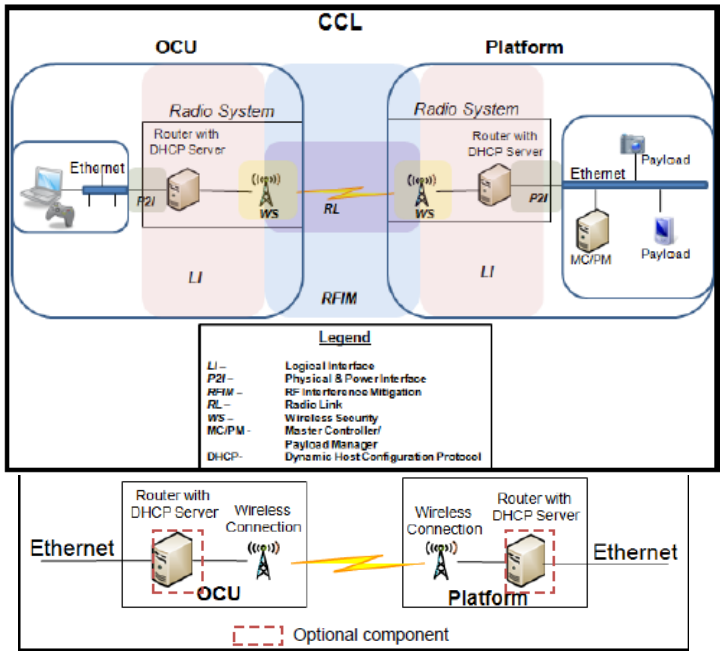
IOP V0 Content – Comms IOP

- Specifies the communications standards, requirements, and conformance approach.

4.4 Usage of Communications IOP

The Communications IOP will be used by the MATDEV and industry to define communications and radio related requirements for a CCL, to point to applicable sections in the other IOPs, and to define communications related Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

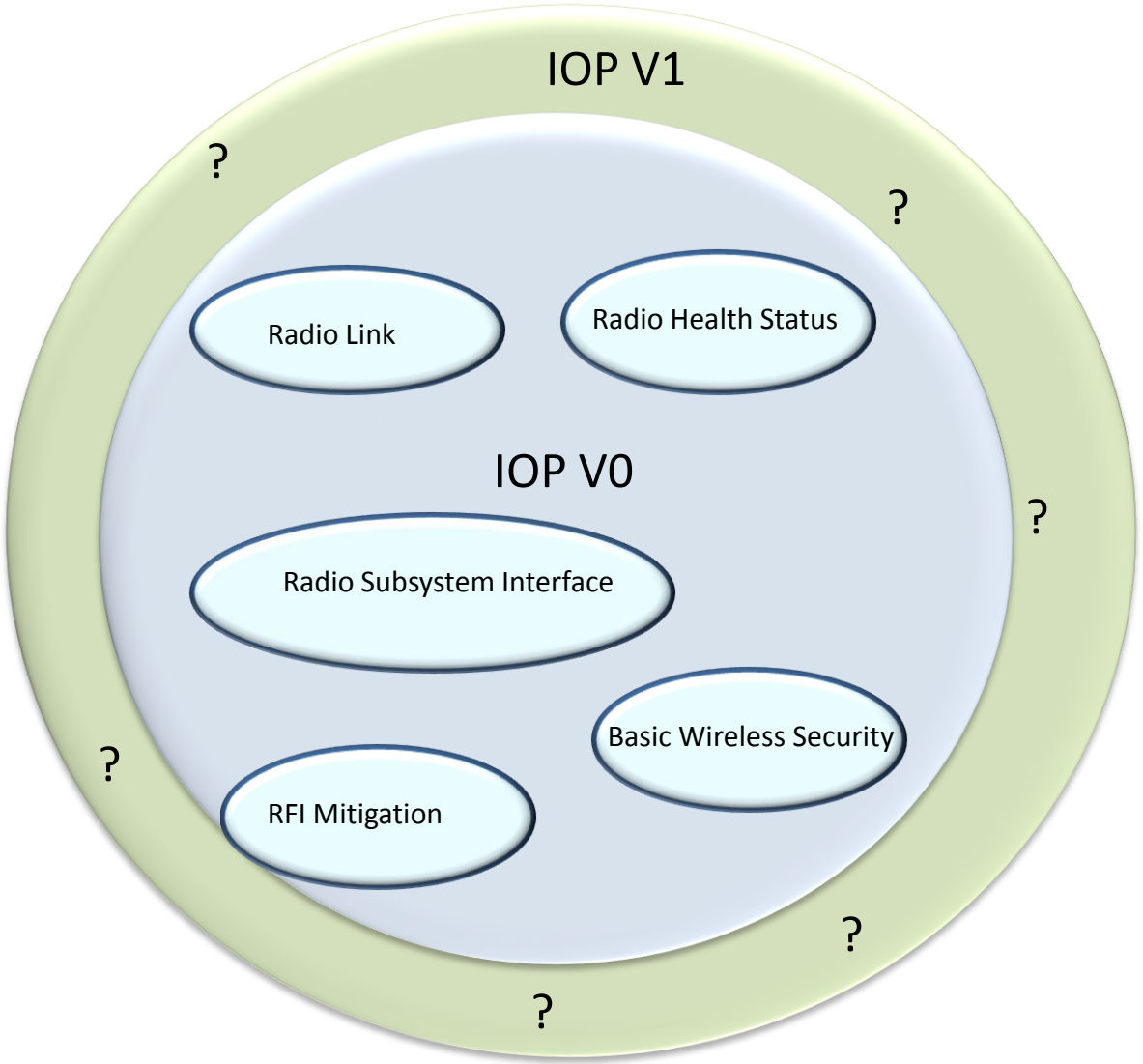
Attribute	Paragraph	Title	Values
Waveform	3.3	Air Interface/ Waveform	OFDM, COFDM, DDL, CDL, None
OCU to Platform Communications	3.5 - 3.6	Radio & Tethered Communications	CCL, Optical Tether, Wired Tether, None
RF Connector	4.1.1.2	Antenna Connectors	SMA-female, TNC-female , N type-female, MMCX-female
Input Power	4.1.2	Power	Auto-sense 10-28 VDC
Network Interface Standard	4.2.1	Network Standard	Ethernet, USB 2.0, RS232, RS422, RS485
IP Addressing	4.2.2	Addressing Standard	IPv4, IPv6
On-board Network	4.2.3	Data Packet Handling	Flat Network with static IP assignment, Flat Network with DHCP, Routed Network, None
Channel Bandwidth Agility	4.3.2	Bandwidth Selection	Adjustable, None
Wireless Encryption	4.4.1	Encryption	AES128, None
Encryption Bypass	4.4.2	Encryption Bypass	Bypass, None
Frequency Band Selectable	4.5.1	Frequency Band Selection	Support Multiple Frequency Bands, None
Data Rate	4.6.2	Data Rate	>1.8 Mbps for video, >200 kbps for telemetry, >2.0 Mbps for video and telemetry None



Example requirement associated w/ this Interoperability Attribute Value

[COMM 008] A CCL system with an On-Board Network Interoperability Attribute Value of Routed Network shall be capable of enacting Dynamic Host Configuration Protocol (DHCP) to enable the automatic IP address assignment of payloads and other Ethernet systems.

IOP V0 Scope – Communications IOP



IOP V0 – What does it mandate? (Comms IOP)

*DHCP only required when specified

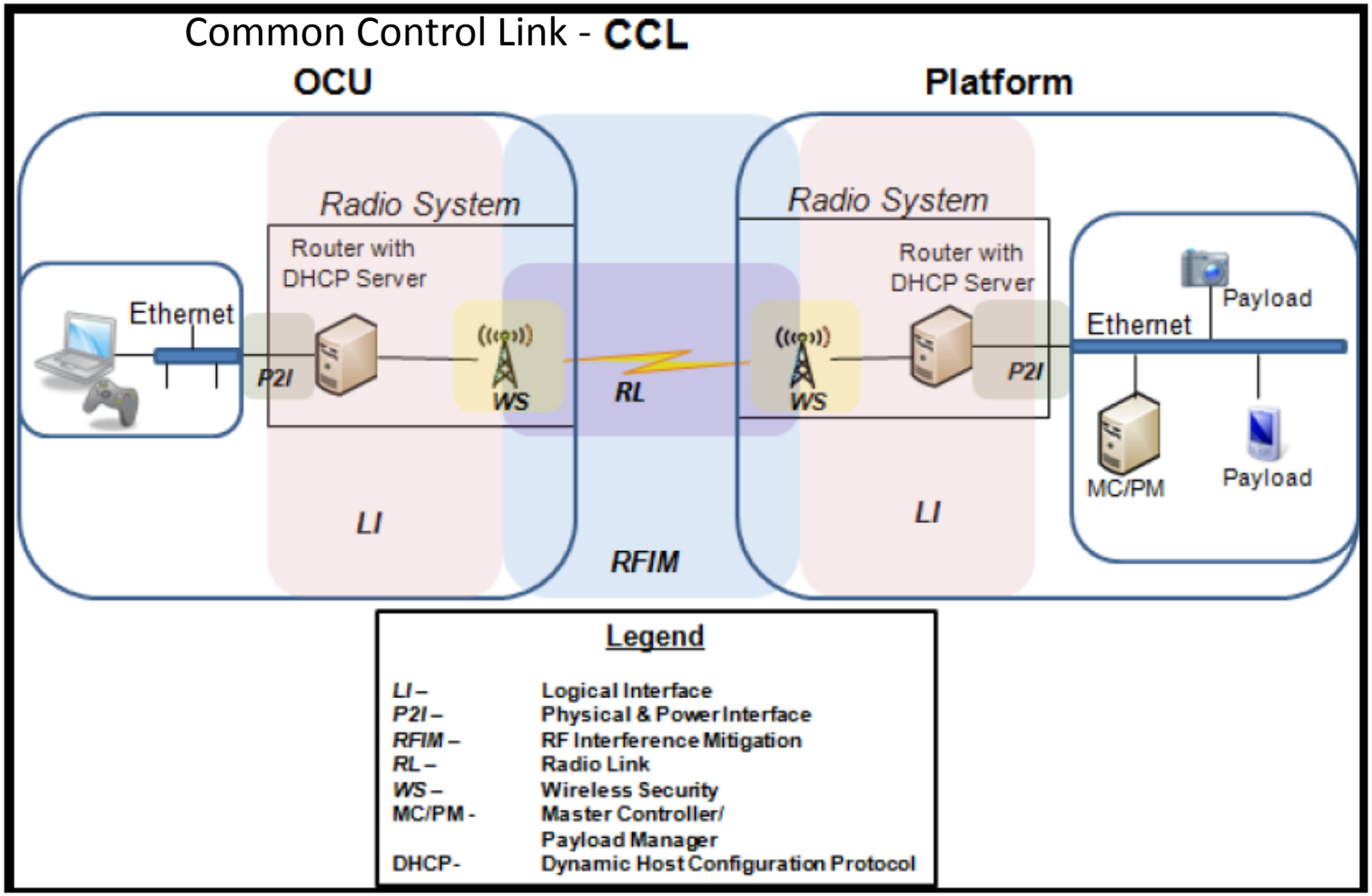


Figure 3-2 CCL Boundary Diagram

IOP V0 – What does it mandate? (Comms IOP – 1 of 5)

Radio Physical Connectors & Power

[COMM 001] The radio or tether communication system shall employ a connector(s) defined in the *Payloads IOP* or provide a conversion to interface with the UGV Platform.

[COMM 002] The antenna connector of the radio system shall use any of the following common polarity industry connectors to interface with the antenna:

- SMA-female
- TNC-female
- N type-female
- MMCX type-female

[COMM 003] The antenna port of the radio system shall be weatherproof, low loss with 50 Ohm impedance.

[COMM 004] The CCL input power shall be auto-ranging supporting a minimum voltage range of 10 to 28 VDC.

IOP V0 – What does it mandate? (Comms IOP – 2 of 5)

ROBOTIC SYSTEMS JPO

Radio Logical Interfaces (1 of 2)

[COMM 005] The primary on-board network standard shall be derived from the IEEE 802.3 standard for Ethernet communication.

[COMM 006] The secondary standard will be for USB 2.0 or higher and/or RS232/422/485. USB standard will be derived from the USB Forum standards. The RS232/422/485 standard will be derived from EIA/TIA (232/422/485) standards.

[COMM 007] The primary addressing standard for IOP V0 shall be IP version 4 (IPv4) and will accommodate for future IP version 6 (IPv6) migration per DoD guidelines.

[COMM 008] A CCL system with an On-Board Network Interoperability Attribute Value of Routed Network shall be capable of enacting Dynamic Host Configuration Protocol (DHCP) to enable the automatic IP address assignment of payloads and other Ethernet systems.

[COMM 009] The CCL system shall be capable of enacting Routing for IP packets between CCLs and system they support.

[COMM 010] The CCL system shall support routed type networks.

[COMM 011] The IP address assignment list shall be provided in accordance with JAUS transport section 4.1.4 of the *JAUS Profiling IOP*.

IOP V0 – What does it mandate? (Comms IOP – 3 of 5)

ROBOTIC SYSTEMS JPO

Radio Logical Interfaces (2 of 2)

[COMM 012] The CCL system shall be able to manage packets within the IEEE 802.3 protocol standards per Figure 4-1.

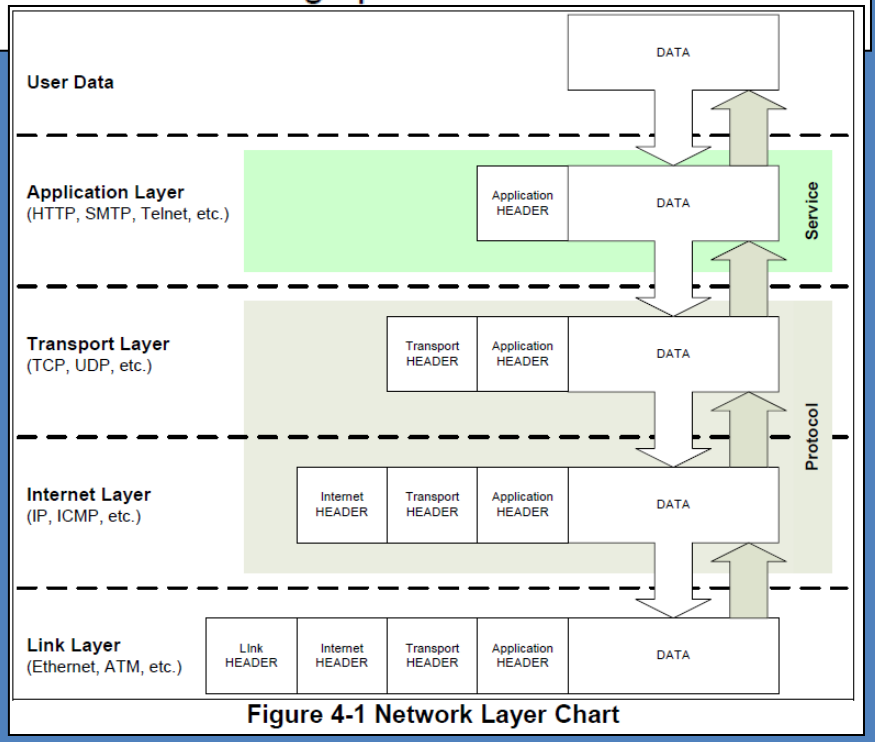


Figure 4-1 Network Layer Chart

[COMM 013] The CCL radio shall be IP addressable for plug and play capability. IP shall be the standard protocol for CCL Network Layer.

IOP V0 – What does it mandate? (Comms IOP – 4 of 5)

ROBOTIC SYSTEMS JPO

Radio Link

[COMM 014] The radio shall be capable of tuning across the frequency band of operation in increments of one channel bandwidth (BW).

[COMM 015] The radio shall be able to change the BW of the radio channel transmission through JAUS messages as defined in *JAUS Profiling IOP* and the *Custom Service Messages & Transports* document.

[COMM 016] The radio shall be able to turn off and on RF transmissions of the communications link through JAUS messages as defined in *JAUS Profiling IOP* and the *Custom Service Messages & Transports* document.

[COMM 017] The user shall be able to set the maximum RF transmit power output of the radio through JAUS messages as defined in *JAUS Profiling IOP* and the *Custom Service Messages & Transports* document.

[COMM 018] The user shall be able to set the radio minimum RF transmit power output through JAUS messages as defined in *JAUS Profiling IOP* and the *Custom Service Messages & Transports* document..

[COMM 019] The radio communications shall be capable of ceasing/ terminating RF transmissions when tether communications is employed.

IOP V0 – What does it mandate? (Comms IOP – 5 of 5)

ROBOTIC SYSTEMS JPO

Encryption

[COMM 020] The radio shall be capable of employing Advanced Encryption Standard (AES) with a minimum 128-bit key length or similar encryption protocol that will provide the same or better protection.

[COMM 021] The radio shall be able to bypass encryption using JAUS messages in accordance with the *Custom Service Messages & Transports* document.

RFI Mitigation

[COMM 022] The radio communications system shall be capable of changing the frequency band of operation either by swapping hardware or through software commands.

[COMM 023] The communications link shall be able to operate without degradation of radio communications range performance on second adjacent channels transmitting in the same immediate area of operation.

Data Rate

[COMM 024] The radio communications video link shall support a data rate of 1.8 Mbps or better.

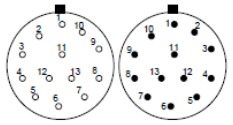
[COMM 025] The radio communications telemetry and audio link shall support a data rate of 200 kbps or better.

[COMM 026] The radio communications link that combines video, telemetry and audio products to a single link shall support a data rate of 2.0 Mbps or better.

IOP V0 – What does it mandate? (Comms Interoperability Attributes)

Attribute	Paragraph	Title	Values
Waveform	3.3	Air Interface/ Waveform	OFDM, COFDM, DDL, CDL, None
OCU to Platform Communications	3.5 - 3.6	Radio & Tethered Communications	CCL, Optical Tether, Wired Tether, None
RF Connector	4.1.1.2	Antenna Connectors	SMA-female, TNC-female , N type-female, MMCX-female
Input Power	4.1.2	Power	Auto-sense 10-28 VDC
Network Interface Standard	4.2.1	Network Standard	Ethernet, USB 2.0, RS232, RS422, RS485
IP Addressing	4.2.2	Addressing Standard	IPv4, IPv6
On-board Network	4.2.3	Data Packet Handling	Flat Network with static IP assignment, Flat Network with DHCP, Routed Network, None
Channel Bandwidth Agility	4.3.2	Bandwidth Selection	Adjustable, None
Wireless Encryption	4.4.1	Encryption	AES128, None
Encryption Bypass	4.4.2	Encryption Bypass	Bypass, None
Frequency Band Selectable	4.5.1	Frequency Band Selection	Support Multiple Frequency Bands, None
Data Rate	4.6.2	Data Rate	>1.8 Mbps for video, >200 kbps for telemetry, >2.0 Mbps for video and telemetry None
Off-Board Network Attributes	5.	Network Interoperability Attributes	OCU/Platform PTP paired, OCU/Platform PTP independent, OCU/Repeater/Platform, Mesh/MANET Network, Cloud Network

IOP V0 Content – Payloads IOP



Receptacle	Plug
- Sockets	- Pins
- Platform Side	- Payload Side
- Nominal Key	- Nominal Key

Pin #	Signal	PIN #	Signal
1	GND	8	C+
2	A+	9	B-
3	A-	10	B+
4	D+	11	PWR
5	D-	12	PWR
6	GND	13	NA

Figure 4-2 Interoperability Connector "A" Diagram

- Specifies the payload classification, standards, requirements, and conformance approach.

4.5 Usage of Payloads IOP

The *Payloads IOP* will be used by the MATDEV and industry to define payload related requirements for both payloads themselves and UGV platforms, to point to applicable sections in the other IOPs, and to define payload related Interoperability Attributes that may be selected by the MATDEV to impose interoperability requirements into acquisition contracts.

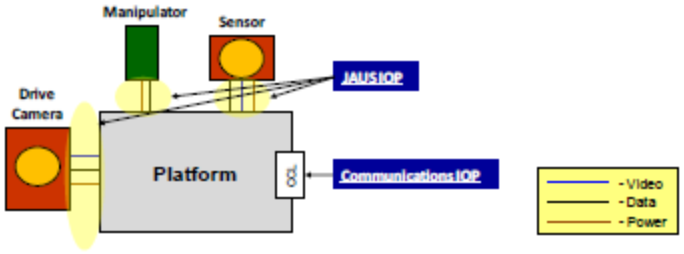
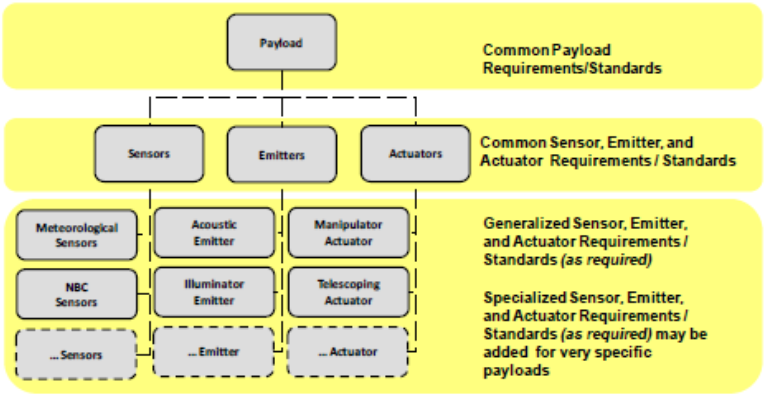


Figure 1-1 Payload IOP Relationships

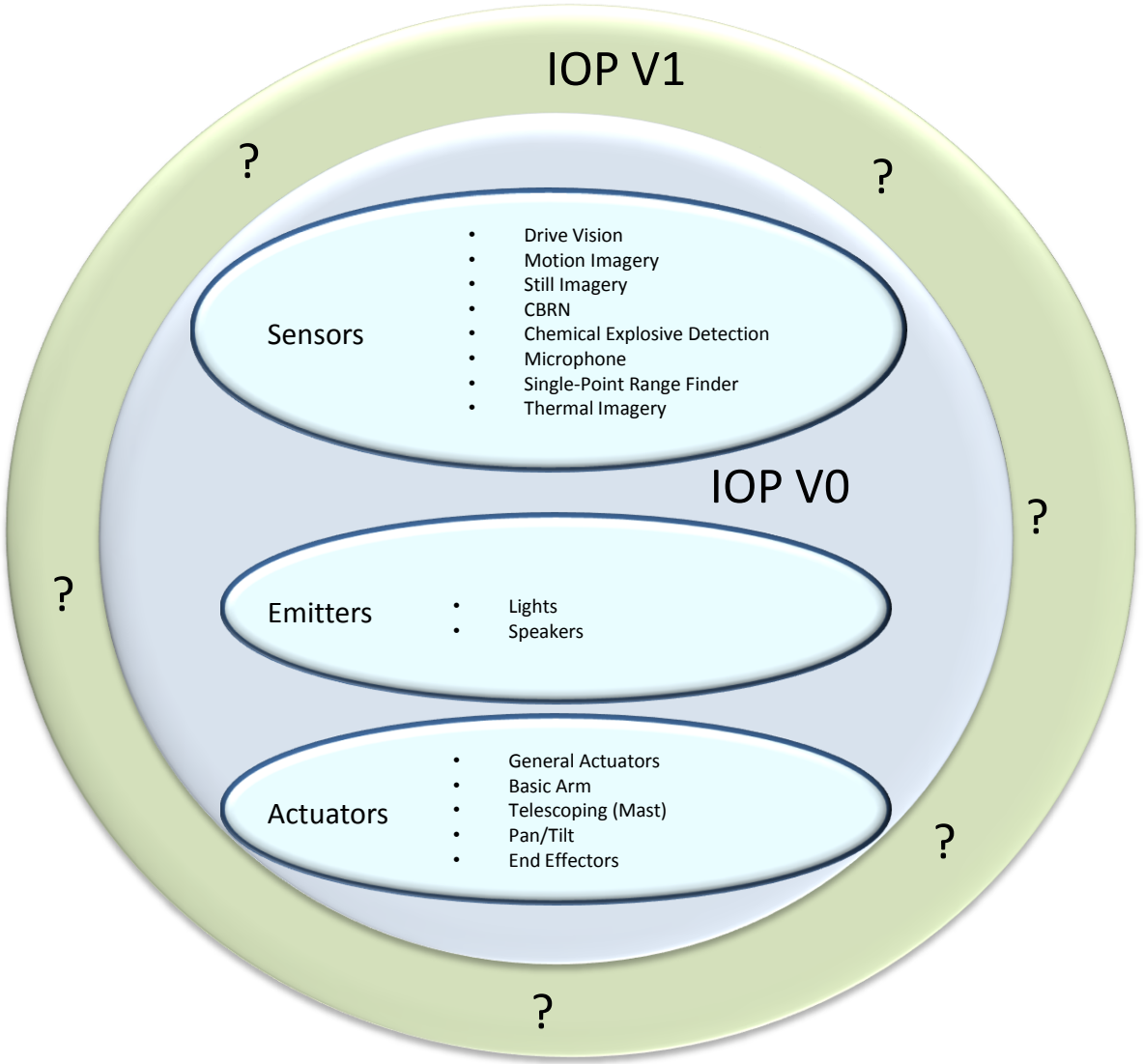
IOP	Paragraph	Title	Values
Physical Mounting	4.3	Physical Mounting Requirements	Picatinny Rail Option Optical Bench Option
Power	4.4	Electrical Power Requirements	Power Attribute A Power Attribute B
Interoperability Connector	4.5	Data Connection Requirements	Connector A Connector B
Generalized Sensor	6	Generalized Sensor Requirements	Digital Motion Imagery Analog Motion Imagery Still Imagery CBRN Sensor Microphone Range Finder Thermal Sensor PTZ Camera
Generalized Emitter	9	Generalized Emitter Requirements	Light Speaker
Generalized Actuator	12	Generalized Actuator Requirements	Basic Manipulator Basic Pan Tilt Manipulator Telescoping Mast



Example requirement associated w/ this Interoperability Attribute Value

[PAY 009] Payloads implementing the digital drive and motion imagery capability shall do so by implementing the digital video component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.1, and will support H.264 or MPEG2 video standards at a minimum.

IOP V0 Scope – Payloads IOP



IOP V0 – What does it mandate? (Payloads IOP – 1 of 6)

ROBOTIC SYSTEMS JPO

General

[PAY 001] Unless specified otherwise, Payload command, control and status messages shall be implemented using the SAE AS-4 JAUS standards as profiled by the *UGV IOP SAE JAUS Profiling Rules* associated with any required (specified) Interoperability Attributes.

[PAY 002] Unless specified otherwise, Custom payload command, control and status messages shall be implemented in accordance with the *RS JPO, UGV IOP Custom Service Messages and Transports*.

[PAY 003] Unless specified otherwise, the payload transport shall be identical to the vehicle transport in accordance with the Transport Interoperability Attribute, described in section 5.6.1.3 of the *UGV IOP Overarching IOP*.

Physical Mounting

[PAY 004] If the Picatinny Rail Interoperability Attribute is selected, the payload shall be capable of mounting to a rail in accordance to MIL-STD-1913.

[PAY 005] If the Optical Bench Interoperability Attribute is selected, the payload shall be capable of mounting to a plate that has 1" X 1" grid spacing, ¼-20 UNC threaded holes. Configuration, quantity, material characteristics, depth, and tolerances to be listed by the platform program.

IOP V0 – What does it mandate? (Payloads IOP – 2of 6)

ROBOTIC SYSTEMS JPO

Electrical Power & Data

[PAY 006] If a Power Interface Interoperability Attribute is selected, the power provided by the platform will meet the requirements listed for the power attribute selected, and the payload will accept the power listed in the power attribute that was selected.

Power Interface	Voltage	Max Power (Watts)	Max Current (Amps)
A	12 VDC	60 Watts	5 Amp
B	24 VDC	120 Watts	5 Amp

Table 4-1 Power Attributes

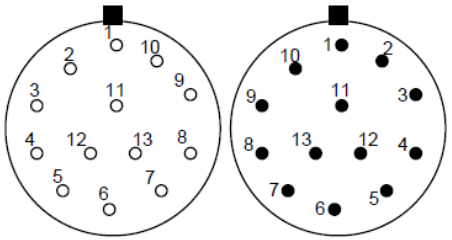
[PAY 007] The data format will be compliant with IEEE 802.3ab (Gigabit Ethernet), as defined by *UGV IOP Overarching Profile*.

IOP V0 – What does it mandate? (Payloads IOP – 3of 6)

ROBOTIC SYSTEMS JPO

Physical Connectors

[PAY 008] If a Connector Interoperability Attribute is selected, the connector will meet the MIL-DTL-38999L Series II connector selected, with the keyway and pinout identified for the connector listed.

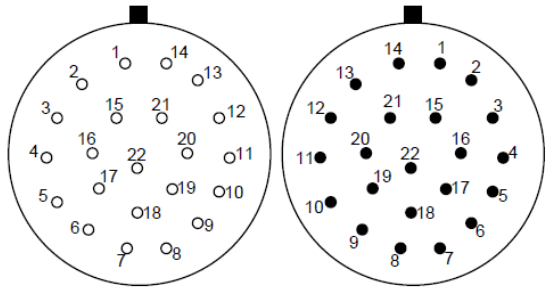


Receptacle
- Sockets
- Platform Side
- Nominal Key

Plug
- Pins
- Payload Side
- Nominal Key

Figure 4-2 Interoperability Connector "A" Diagram

Pin #	Signal	PIN #	Signal
1	GND	8	C+
2	A+	9	B-
3	A-	10	B+
4	D+	11	PWR
5	D-	12	PWR
6	GND	13	NA
7	C-		



Receptacle
- Sockets
- Platform Side
- Nominal Key

Plug
- Pins
- Payload Side
- Nominal Key

Figure 4-3 Interoperability Connector "B" Diagram

Pin #	Signal	PIN #	Signal
1	A-	13	B-
2	C+	14	A+
3	C-	15	D-
4	GND	16	GND
5	PWR	17	GND
6	PWR	18	PWR
7	PWR	19	GND
8	PWR	20	GND
9	PWR	21	D+
10	PWR	22	GND
11	GND		
12	B+		

IOP V0 – What does it mandate? (Payloads IOP – 4 of 6)

ROBOTIC SYSTEMS JPO

Video & Imagery Payloads

[PAY 009] Payloads implementing the digital drive and motion imagery capability shall do so by implementing the digital video component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.1, and will support H.264 or MPEG2 video standards at a minimum.

[PAY 010] Payloads implementing the analog drive and motion imagery capability shall do so by implementing the analog video component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.4, and will support the NTSC video standards at a minimum.

[PAY 011] Payloads implementing the still imagery capability shall do so by implementing the still image component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.2, and will support JPEG or JPEG2000 image standards at a minimum.

[PAY 015] Payloads implementing the thermal sensor capability shall do so by implementing the appropriate imagery component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*. The formats will be the same as those presented in 6.1.1 (for thermal motion imagery) and 6.1.2 (for thermal still imagery) in this document.

[PAY 016] Payloads implementing the PTZ camera sensor capability shall do so by using the pan tilt video sensor attribute in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*.

IOP V0 – What does it mandate? (Payloads IOP – 5 of 6)

Microphone

[PAY 013] Payloads implementing the microphone capability shall do so by implementing the microphone component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.6.

Range Finder

[PAY 014] Payloads implementing the range finder sensor capability shall do so by implementing the range finder component in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.3.

CBRN Payloads

[PAY 012] Payloads implementing the CBRN sensor capability shall do so by implementing the Common CBRN Sensor Interface.

CCSI - http://www.jpeocbd.osd.mil/packs/Default.aspx?pg=860

IOP V0 – What does it mandate? (Payloads IOP – 6 of 6)

ROBOTIC SYSTEMS JPO

Lights & Speakers

[PAY 017] Payloads implementing the lights capability shall do so by implementing the lights attribute in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.7.

[PAY 018] Payloads implementing the speakers capability shall do so by implementing the speaker attribute in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.4.8.

Actuators/Manipulators

[PAY 019] Payloads implementing the basic manipulator capability shall do so by implementing the basic manipulator attributes and attribute options in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.5.2.

[PAY 020] Payloads implementing the basic pan tilt capability shall do so by implementing the basic manipulator attributes and attribute options in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.5.3.

[PAY 021] Payloads implementing the telescoping mast capability shall do so by implementing the telescoping mast attribute in accordance with the definition and rules specified in the *UGV IOP SAE JAUS Profiling Rules*, Section 4.5.4.

IOP V0 Content – Control IOP

- Specifies Operator Control Unit (OCU) logical architecture, standards, Human-Machine Interface (HMI) requirements, and conformance approach.

4.6 Usage of Control IOP

The Control IOP will be used by the MATDEV and industry to define desired common qualities of controllers. It is acknowledged that there are a variety of types of controllers that make sense for different missions, and the technology related to controllers is evolving rapidly, particularly based on advancements being made in the mobile/smart-phone and gaming markets. The current Control IOP V0 contains desired guidelines for user interfaces for conventional controllers, but does not mandate explicit requirements. Controllers must be capable of communicating JAUS-based messages as defined in this IOP package, and must interface with the CCL as defined in the *Communications IOP*. The primary intent of the Control IOP is to promote an interoperable Human Machine Interface (HMI), which means that the relationship between the controller and the human operator must be modular based on minimized training for operation among different systems. If controllers can support the JAUS-based messages described in this IOP package, then interoperable messages will become the interface between the controller and the UGV platform.

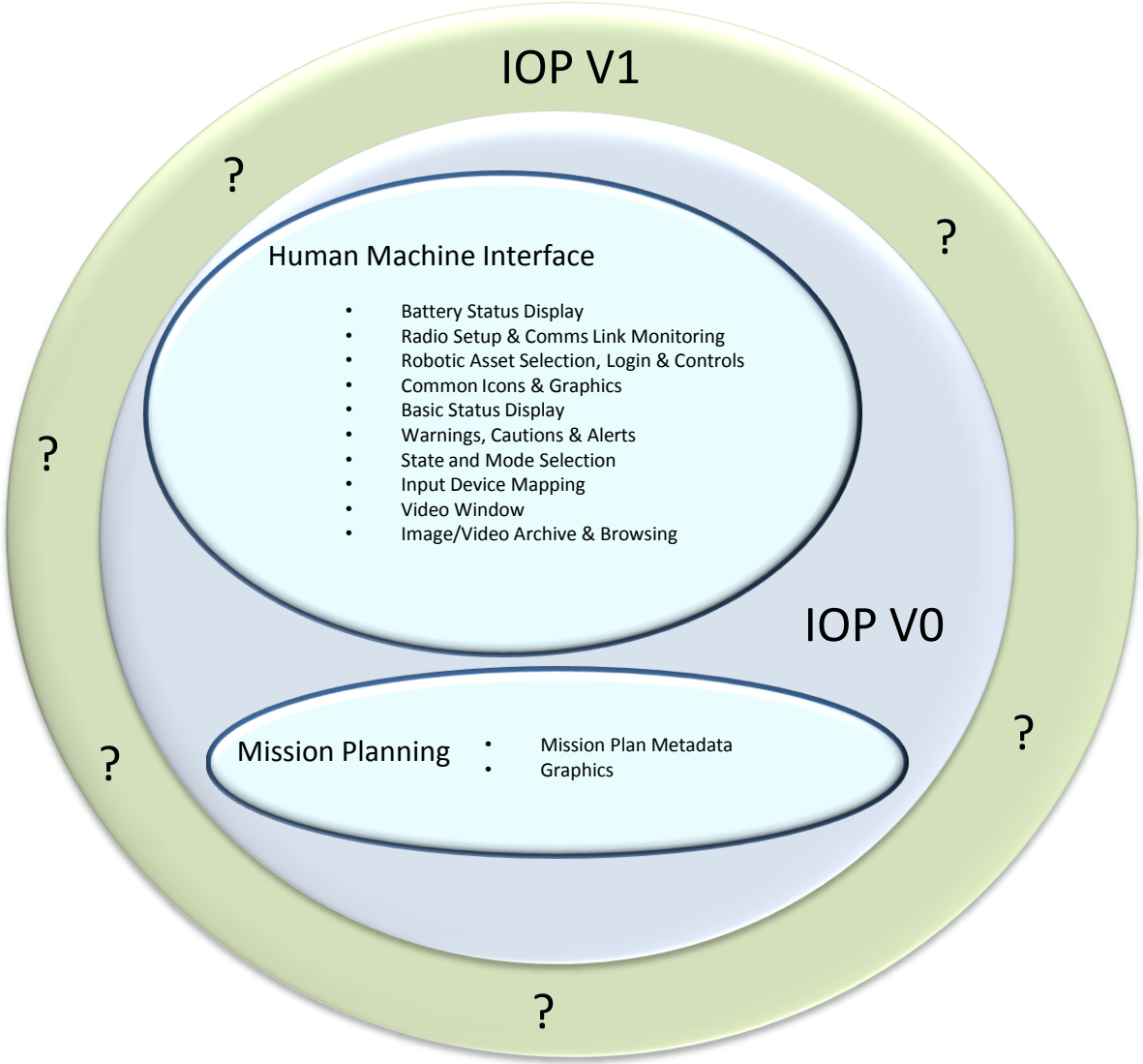
For example, if a controller operator presses a keypad arrow to turn right, then an interpretable message command will be received and understood by the UGV platform. If another controller utilizes a joystick to turn right, then the UGV platform should receive an identical message as that sent from the first controller. Similarly, user input to turn right on a smartphone type accelerometer device, a speech-based device, a motion-recognition device, or other innovative controller technology should all result in an identical, interpretable JAUS-based message being received by the UGV platform.

Example: Defines Hardware & Software Access Levels for OCUs

3.10.4.1 Pan/Tilt

ID	Function/Task	Category	Control (C) or Status (S)	Access Level	Graphic	Reference
CTRL-Actuators-1	control pan/tilt azimuth	Payload-Pan/Tilt	C	HW, SW1		
CTRL-Actuators-2	control pan/tilit elevation	Payload-Pan/Tilt	C	HW, SW1		
CTRL-Actuators-3	view pan/tilt functional status (WCA implications)	Payload-Pan/Tilt	S	SW2		

IOP V0 Scope – Control IOP



IOP V0 – What does it mandate? (Control IOP)

ROBOTIC SYSTEMS JPO

General Controllers

All IOP compliant controllers will be capable of communicating with platforms using the JAUS-based message set contained within the other IOP documents. This Control IOP serves to provide additional guidance as to the design of controllers.

Platform Discovery will be implemented as specified in the UGV Interoperability Profile (IOP) – *JAUS Profiling Rules* document.

Additionally, Control IOP contains detailed guidance on the following:

- HMI recommended design practices (hardware & software)
- Recommended OCU design attributes & interfaces by size/weight class
- Extensive listing of recommended control standards reference documents

IOP V0 Content – SAE JAUS Profiling Rules

- Specifies the manner in which the SAE AS-4 JAUS standards have been profiled
- Includes clarification & additional content to define interoperability between controllers and UGVs as well as intra-UGV (platform/subsystem) interoperability..

4.7 Usage of JAUS Profiling Rules IOP

The *JAUS Profiling Rules IOP* will be used primarily by industry as implementation guidance for complying with the requirements defined within all of the other IOPs. It provides the product-level JAUS-based message implementation guidance, and reference to the appropriate SAE AS-4 JAUS documents. Additionally, the JAUS *Profiling Rules IOP* will be used by the MATDEV in developing System Integration Labs (SILs) for verifying that the IOPs achieve the desired outcomes, as well as assessing the compliance of vendor products to the IOPs.

Table 4.2-2: Component and Service Requirements for Basic Platform Manager

Basic Platform Manager Component	
Service	**Reference**
urn:jaus:jss:core:Discovery, v1.0	AS5710 JAUS Core Service Set
urn:jaus:jss:core:Liveness, v1.0	AS5710 JAUS Core Service Set
urn:jaus:jss:ugv:PowerPlantManager, v0.1	AS6091 JAUS UGV Service Set
urn:jaus:jss:ugv:Odometry, v0.1	AS6091 JAUS UGV Service Set
urn:jaus:iop:platformmanager:PlatformMode, v1.0	Custom Services, Messages, and Transports
urn:jaus:iop:platformmanager:HealthMonitor, v1.0	Custom Services, Messages, and Transports
urn:jaus:iop:platformmanager:PresetPose, v1.0	Custom Services, Messages, and Transports

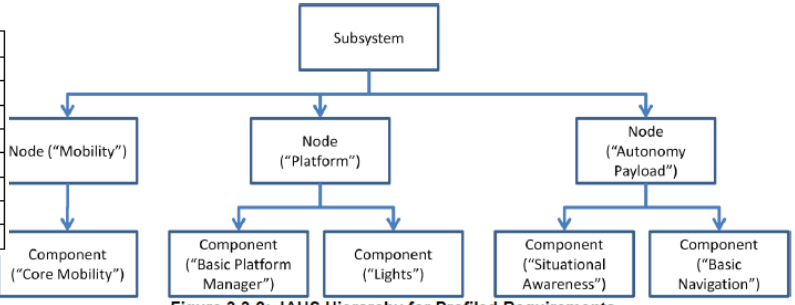


Figure 3.3-2: JAUS Hierarchy for Profiled Requirements

IOP V0 Content – SAE JAUS Profiling Rules (cont.)

Message(s)	Concept	Interpretations
ID 4508: ReportPowerPlantStatus	Reporting Types	Only the record or records that apply to the power plant capabilities of the vehicle shall be used when sending a ReportPowerPlantStatus message. For example, if a vehicle with a diesel engine and battery is reporting information, it shall provide the batteryStatus and dieselEngineStatus records, and not the gasolineEngineStatus record.
ID 4506: ReportPowerPlantState	Reporting Types	For reporting engine RPM, the record corresponding to the type of engine (either gasEngineState for a gasoline engine or dieselEngineState for a diesel engine) shall be used.

Mobility Interoperability Attributes (Mobility::*::)			
Attribute	**Modifiers**	**Values**	**Parameters**
Core Mobility	Mandatory	Default	
Drive Timeout	Mandatory	Default	**Drive Timeout** (default = 1 second)
			Drive Frequency (default = none)
			Drive Recovery Time (default = 1 second)
Safety Requirements	Mandatory	Default	
Remote Control (RC)	Selectable	Default	
Teleoperation (Teleop)	Selectable	Default	
Basic Navigation (BN)	Selectable	Local	
		Global	
Leader Follower (LF)	Selectable	Default	
Mobility Limits	Selectable	Default	
Velocity State Driver	Selectable	Default	

Mobility Attribute Options (Mobility::*)

Table 4.1-1: Core Attributes

Attribute Name	Attribute Values	Description
Core Services [Mandatory]	Default	Specifies which JAUS core services are required and any clarifications on their use.
Access Control [Mandatory]	Default	Defines rules for using JAUS Access Control service authority codes and Access Control Timeout.
ID Assignment [Mandatory, Mutually Exclusive]	Static	Uses static assignment of JAUS addresses for Nodes and Components.
	Centralized	Uses a centralized, DHCP like method for assignment of JAUS addresses for Nodes and Components.
	IP Based	Defines a method for assigning JAUS addresses based on unique IP addresses.
Transport [Mandatory]	JUDP	Specifies that the JAUS over UDP transport is used as specified in AS5669A JAUS/SDP Transport Specification.
	JTCP	Specifies that the JAUS over TCP transport is used as specified in AS5669A JAUS/SDP Transport Specification.
	Custom	Specifies that a custom transport is used.

IOP V0 – What does it mandate? (JAUS Profiling Rules – Representative Example – Basic Platform Management Required Services)

ROBOTIC SYSTEMS JPO

Discovery Service

4.2.1.1.2.1 **Discovery**

The discovery service shall be provided as specified as in *AS5710 JAUS Core Service Set*, with the following additional messaging requirements:

Table 4.2-3: Message Interpretations for Discovery Service

Message(s)	Concept	Interpretations
ID 2B00: QueryIdentification ID 4B00: ReportIdenfitication	Finding and Losing	The QueryIdentification message shall be sent by each component on a subsystem at a rate specified
ID 0B00: RegisterServices	Subsystem Discovery Service	in the Periodicity section. If a corresponding ReportIdentification message is not received within 5 seconds, two more retries will be attempted. If ReportIdentification is still not received, the Discovery service shall be considered lost. When a Discovery service is found after being considered lost, the RegisterServices message shall be sent to the Discovery service containing information on all services the component provides, including the core services.

*This represents additional detail to example shown on Slide #12

IOPV0 – What does it mandate? (JAUS Profiling Rules – Representative Example – Basic Platform Management Required Services)

ROBOTIC SYSTEMS JPO

Liveness Service

4.2.1.1.2.2 **Liveness**

The liveness service provided by the Platform Manager JAUS component shall be used by an OCU or other client to maintain liveness to the Platform Manager.

Power Plant Manager Service

4.2.1.1.2.3 **Power Plant Manager**

The following message interpretations apply for the Power Plant Manager service:

Table 4.2-4: Message Interpretations for Power Plant Manager Service

Message(s)	Concept	Interpretations
ID 4508: ReportPowerPlantStatus	Reporting Types	Only the record or records that apply to the power plant capabilities of the vehicle shall be used when sending a ReportPowerPlantStatus message. For example, if a vehicle with a diesel engine and battery is reporting information, it shall provide the batteryStatus and dieselEngineStatus records, and not the gasolineEngineStatus record.
ID 4506: ReportPowerPlantState	Reporting Types	For reporting engine RPM, the record corresponding to the type of engine (either gasEngineState for a gasoline engine or dieselEngineState for a diesel engine) shall be used.

*This represents additional detail to example shown on Slide #12

IOP V0 – What does it mandate? (JAUS Profiling Rules – Representative Example – Basic Platform Management Required Services)

ROBOTIC SYSTEMS JPO

Odometry Service

4.2.1.1.2.4 **Odometry**

The following message interpretations apply for the Odometry service:

Table 4.2-5: Message Interpretations for Odometry Service

Message(s)	Concept	Interpretations
ID 0515: QueryOdometry	Usage	A value of PLATFORM for the OdometryType shall be used to request the distance traveled by the platform since it began service. A value of TRIP_A shall be used to query the distance traveled on the current trip. The current trip starts whenever an external entity, such as an OCU, issues a ResetOdometry message with a value of TRIP_A.
4516: ResetOdometry	Usage	This message shall be used with a value of TRIP_A to start a new trip.

Health Monitor Service

For IOP Version 0, only the QueryComponentHealth and ReportComponentHealth messages of the Health Monitor service are required. For IOP Version 0, only the Failure, Comms lost, and Emergency health states are required.

The following message interpretations apply for the HealthMonitor service:

Table 4.2-6: Message Interpretations for Health Monitor Service

Message(s)	Concept	Interpretations
ID FF12: ReportComponentHealth	Emergency and Failure Health States	The HealthState field of the ComponentHealthRec shall be set to Failure or Emergency based on the Management service state of a component. If a component does not provide a Management service, these health states are not possible.
	Comms Lost State	If liveness to a component is lost (urn:jaus:jss:core:Liveness service), the Health Monitor service shall report health state as 3: Comms Lost.

*This represents additional detail to example shown on Slide #12

IOPV0 – What does it mandate? (JAUS Profiling Rules – Representative Example – Basic Platform Management Required Services)

ROBOTIC SYSTEMS JPO

Platform Mode Service

4.2.1.1.2.6 **Platform Mode**

There are no notes or interpretations for Platform Mode.

Preset Pose Service

4.2.1.1.2.7 **Preset Pose**

The Preset Pose service is used to set and query/report preset poses for a platform, where a pose refers to a particular orientation and position of various arms, flippers, and manipulators. The following message interpretations apply for the Preset Pose service:

Table 4.2-7: Message Interpretations for Preset Pose Service

Message(s)	Concept	Interpretations
ID FFFD: SetPresetPose	Stow Pose	The Stow pose is defined as a pose where all actuated devices are in a position that best compacts the platform for stowing within its container or other enclosed area.
	Drive Pose	The Drive pose is defined as a pose best suited to normal driving.
	Deploy Pose	The Deploy pose is defined as a pose best suited to deployment of a platform.

*This represents additional detail to example shown on Slide #12

IOPV0 – What does it mandate? (JAUS Profiling Rules – Representative Example – Basic Platform Management Required Services)

ROBOTIC SYSTEMS JPO

Periodicity Guidance for Services

4.2.1.1.3 ***Periodicity***

4.2.1.1.3.1 **Liveness**

- ID 2202: QueryHeartbeatPulse/ ID 4202: ReportHeartbeatPulse - The Platform Manager JAUS component's Liveness service can be used to maintain connectivity to a platform. A rate of at least once per 5 seconds is recommended.

4.2.1.1.3.2 **Health Monitor**

- ID 2202: QueryHeartbeatPulse/ ID 4202: ReportHeartbeatPulse - The Health Monitor shall check for connectivity to each JAUS component on the subsystem at a rate of at least once per 60 seconds for every component on the subsystem, and at least once per second for the Core Mobility JAUS component.

4.2.1.1.3.3 **Discovery**

- ID 2B00: QueryIdentification – A QueryIdentification message shall be broadcast by every JAUS component on the subsystem at a rate of at least once per 5 minutes for the purpose of finding and registering services with the Discovery service.

*This represents additional detail to example shown on Slide #12

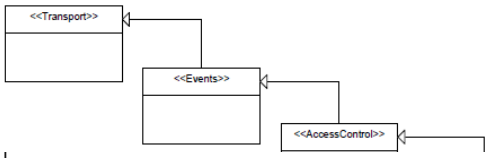
IOP V0 Content – Custom Services, Messages & Transports

- Specifies additional SAE AS-4 JAUS messages and transport protocols required to support the scope of the UGV IOP. Although titled "custom", these messages are published with the end goal of transitioning to the SAE AS-4 JAUS standard(s) for official adoption.

3.3 Communicator Service

name=Communicator
version=0.1
id=urn:jpo:comms:Communicator

Inherits-from AccessControl
name=accessControl
id= urn:jaus:jss:core:AccessControl
version=1.0



Record Name = ReportCommunicatorHealthRec

Field #	Name	Type	Units	Optional	Interpretation
1	<presence_vector>	unsigned byte			
2	<fixed_field> BIT_Results	unsigned byte	one	true	Enumeration values: 0= Passed 1= Failed
3	<fixed_field> Latency	unsigned short integer	second	true	scaled range = [0,1]
4	<fixed_field> DataRate	unsigned short integer	one	true	Measured in Mbps scaled range = [0,1000]
5	<fixed_field> ReceivedSignalPower	unsigned short integer	one	true	Measured in dBm scaled range = [-120,-20]
6	<fixed_field> ErrorVectorMagnitude	unsigned short integer	one	true	Percent scaled range = [0,100]

4.8 Usage of Custom Services, Messages & Transports

The *Custom Services, Messages & Transports* document will be used to define JAUS-based services that are not currently defined in any existing SAE AS-4 JAUS approved document. Currently in V0 the *Custom Services, Messages & Transports* document contains JAUS-based guidance for the following Custom Services: Leader Management, Leader Follower Driver, Communicator, Platform Mode, Health Monitor, Health Reporter, Digital Stream Discovery, and Preset Pose. Currently there are no defined custom messages or custom transports in this document.

It is the intent of the RS JPO for each of the custom services, messages, and transports defined in this package to be recommended for adoption by the SAE AS-4 JAUS Committee, and published in an approved SAE document. Once the services, messages, or transports are approved in a published SAE document, this IOP package will be modified to reference the new p*Services, Messages & Transports* doc document as well).

Additionally, proprietary services, mes into this document.

Table 3.3-1: COMMUNICATOR SERVICE VOCABULARY

Message ID (hex)	Name	Command
Input Set		
2900	QueryCommunicatorCapability	false
2901	QueryCommunicatorConfiguration	false
2902	QueryCommunicatorHealth	false
0901	SetCommunicatorConfiguration	true
Output Set		
4900	ReportCommunicatorCapability	false
4901	ReportCommunicatorConfiguration	false
4902	ReportCommunicatorHealth	false
0902	SetCommunicatorConfigurationResponse	false

IOP V0 Content – Custom Services, Messages & Transports

- New Services defined in V0:
  - Leader Management
  - Leader/Follower Driver
  - Communicator (i.e. radio messages)
  - Platform Mode
  - Health Monitor
  - Health Reporter
  - Digital Stream Discovery
  - Preset Pose

RS JPO UGV IOPs 101

- UGV IOP – What is it?
- IOP V0 – What does it mandate?
- **UGV IOP – How does the Government use it?**
- **UGV IOP – How should industry use it?**
- **Additional Frequently Asked Questions**
- Caveats & Managing Non-Compliant Interfaces

IOP V0 – How does the Government use it?

- RS JPO will instantiate IOP for each Program of Record
  - Consists of "selecting" which Interoperability Attributes apply, and which value(s) are required for each
  - A stand-alone instantiation document will be included as an attachment in the program's RFP
    - » Interfaces will be managed to "product level" requirements
    - » Modules/subsystems/black-boxes will only be managed to "performance level" requirements
- TARDEC UGV Interoperability Lab will perform Verification
  - Verification that IOPs ensure interoperability
  - Verification that products conform to IOPs
- RS JPO will promote proliferation of IOP interfaces
  - Promote industry adoption
  - Promote adoption in all 4 services (RS JPO manages Army & USMC UGVs)
  - Promote adoption/interface in UxS across services
  - Promote interface into other domains (Army COE, manned systems, etc.)
  - Develop DoDAF products (SVs & TVs) around IOPs & promote adoption in DoD DISR, etc.

IOP V0 – How should industry use it?

- Review/understand IOP requirements
- Develop products IAW IOPs
  - Platforms
  - Payloads
  - Radios
  - Controllers
  - Software systems
- Voice technical concerns back to gov't
- Help gov't shape future iterations of IOP

Additional Frequently Asked Questions

- How does IOPs' usage of JAUS conflict with STANAG 4586?
- How does IOPs' usage of JAUS conflict with ROS?
- What are S/W Operating System requirements?
- What does the IOP mandate for Information Assurance?
- How does IOP relate to AEODRS?

How does IOP's JAUS preference relate to STANAG 4586?

- UAVs have different technical requirements than UGVs
- UAV control tends to favor higher message reliability but can tolerate higher latency
  - STANAG 4586 more appropriate for this circumstance
  - Aerial environment is less complex & system autonomy is higher
- UGV control tends to favor lower latency but can tolerate lower message reliability (for teleoperation)
  - JAUS more appropriate for this circumstance
  - Ground environment more complex & system autonomy is lower
- As UGVs mature in terms of autonomy (or comms enhancements), standards such as STANAG 4586 may become more appropriate

How does IOP's JAUS preference relate to Robot Operating System (ROS)?

- JAUS is:
  - A mandated SAE standard for messaging between elements of an unmanned ground system
- ROS is:
  - A software framework (development, management, deployment, and run-time environment) for heterogeneous elements of an unmanned system
  - Open Source and hosts a repository containing hundreds of user developed functionality specific packages, stacks, elements, etc.
- IOPs view ROS elements as functional modules with well defined interfaces
  - ROS/JAUS interoperability is supportable through implementation of a ROS/JAUS bridge/interface device
- The SAE AS-4 JAUS Committee is evaluating the utility of defining a JAUS interface with ROS

- JAUS and ROS are not incompatible, however if both are used then care must be taken on dividing certain software functions
- Due its widely distributed and rapid development, many functions of ROS may currently be unreliable or subject to multiple interpretations

What are the software Operating System (OS) requirements?

- IOP does not favor any particular OS
- The intent is for any subsystem to use an OS of their choosing, given that they can recognize, understand, and send IOP compliant messages
  - Anything internal to each "black box" (such as algorithms, etc.) should be fully designed by its developer

What does the IOP mandate for Information Assurance (IA)?

- IOP does not attempt to define how encryption requirements are implemented (i.e. algorithms, etc.)
- IOP's focus is currently on how to use interoperable messages to accomplish the following:
  - Query/report available encryption types
  - Turn off / turn on encryption modes
- Comms IOP does specify that all IOP/CCL radios must support AES-128 encryption, or equivalent, at a minimum.

How does UGV IOP relate to Navy AEODRS Program?

- The Advanced EOD Robotic System (AEODRS) Inc. I program was initiated prior to the development of IOP V0.
- All AEODRS Architecture Description Documents (ADDs), Module Performance Specs (MPS'), and ICDs were reviewed as part of IOP V0 development
- IOP V0 represents a super-set to AEODRS interface requirements
  - AEODRS interfaces were developed for a single platform
  - IOP developed for all future UGV platform types
- IOP V0 is ~95% common w/ AEODRS interface requirements; teams currently working together to resolve:
  - Discovery triggering mechanism (active vs. passive)
  - JAUS ID assignment schema
  - Autonomy & behaviors – AEODRS includes some that IOP does not
  - Access control – IOP includes requirements that AEODRS does not
- NAVEODTECHDIV is involved in IOP development
- RS JPO attends all AEODRS technical reviews
- Intent is for AEODRS Inc II & Inc III to utilize IOPs

RS JPO UGV IOPs 101

- UGV IOP – What is it?
- IOP V0 – What does it mandate?
- UGV IOP – How does the Government use it?
- UGV IOP – How should industry use it?
- Additional Frequently Asked Questions
- **Caveats & Managing Non-Compliant Interfaces**

RS JPO Interoperability Effort…

- Is in support of modularity
- Is in support of commonality
- Is open source and widely available
- Is continually evolving
- Is **NOT** a limit on innovation
- Is **NOT** a set of proprietary standards
- Is **NOT** an end in itself, but a means to an end
- Is **NOT** added on at the end of a program
- Is **NOT** a replacement for systems engineering

Interoperability vs. Systems Engineering

- Good Interoperability profiles ensure that the interfaces work.
- Good Systems Engineering ensures that the system works.

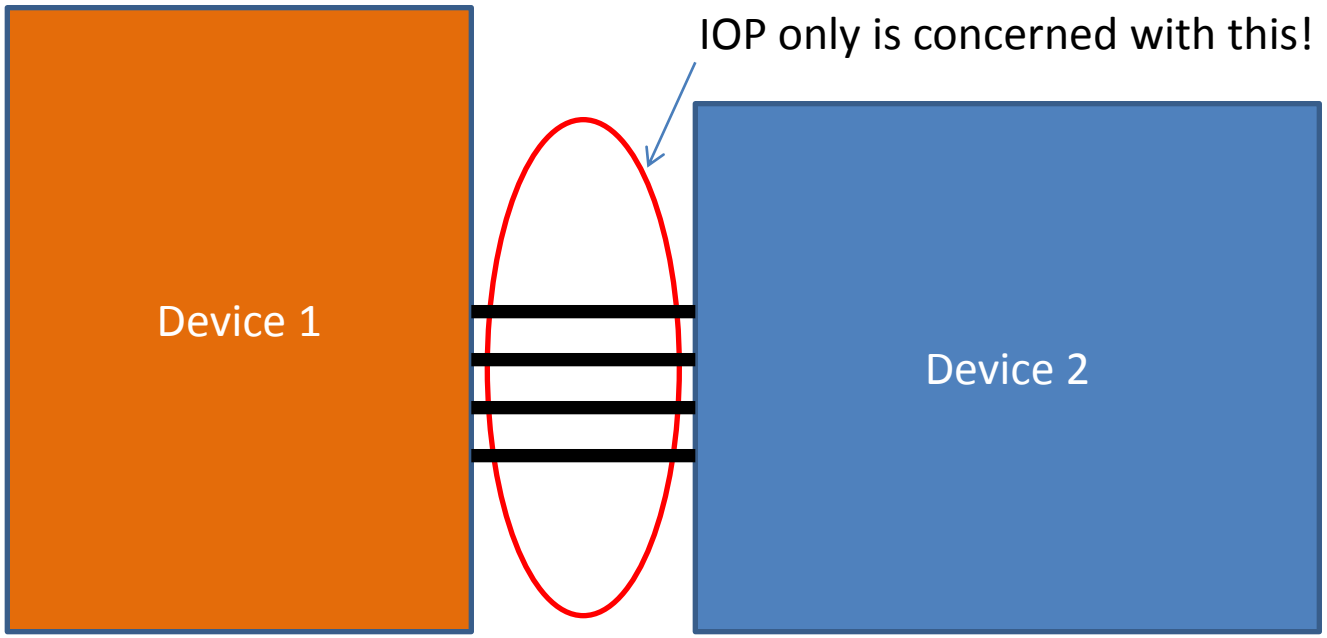
If the interfaces connect, draw power, and pass correct data messages, they are interoperable.

This does not necessarily mean that the system will work well, or be practical.

The resultant system may even be detrimental, without good systems engineering!

Interoperability Caveats

- In other words, a system that is interoperable may not necessarily be a very good system.
- In a perfect world, interoperability does not care what is on the other side of the interface.



Interoperability Common Misconceptions

- Certain capabilities have nothing to do with interoperability, although they are supported by some interoperability attributes
  - For example, stair climbing
    - Stair climbing is not something that IOPs need to specify
    - However, the mobility & actuation related interoperable messages can be used to provide stair climbing
    - Also, interoperability can enable management of different poses or modes, one of which may be stair climbing

Interoperability - Examples

- Interoperability will allow a 500 lb arm to be added to a 10 lb robot as long as the interfaces are correct.
- Interoperability will allow RF to be used as long as both sides meet the correct interfaces, even if the environment is a series of steel plates. Practical solution may suggest a fiber optic tether.

Use of the IOPs

- The RS JPO IPT will select which portions of the IOP will be used, for a given program.
- In most cases, one of the accepted interface standards will be used.
- In some cases, other interfaces may be used with the understanding that the system may not be interoperable with other systems.
  - This decision will be made by the RS JPO IPT after assessing the design trade space for the system.

Hypothetical Example #1
5 Pound Robot

- Attributes selected:
  - No standard physical interfaces
  - No standard power standard
  - Use the RF radio standards
  - Use the JAUS messages
- What does this allow?
  - The system can be small and energy efficient
  - The robot can be controlled by other controllers

Hypothetical Example #2
Modular Robot

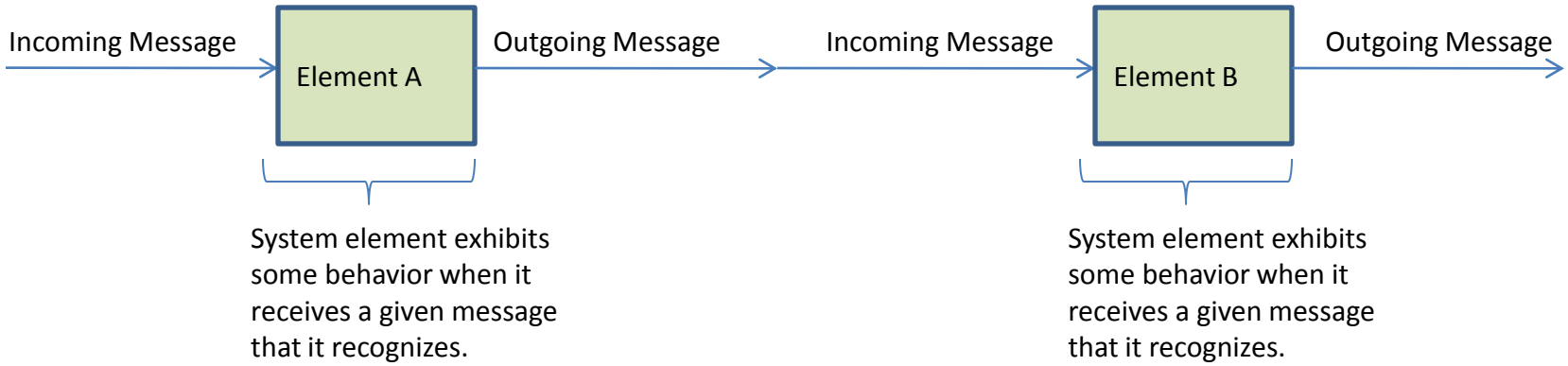
- Attributes selected:
  - Use 4 Picatinny rails, 4 “B” connectors
  - Use the 24 volt system
  - Use the JAUS messages
- What does this allow?
  - Any new payload that can be attached to a Picatinny rail, that uses 24 VDC, “B” connectors, and communicates with the JAUS messages will work with the system

Hypothetical Example #3
Partial Interoperable Robot

- Attributes selected:
  - Use the JAUS messages for 2 payload ports
  - Use the "B" style connectors at 12 VDC
  - Allow the use of vendor specific connectors, cameras, and arms for all other devices
- What does this allow?
  - The robot can use camera, arms, etc… optimized for use on this platform, while also allowing for additional interoperable payloads in the future

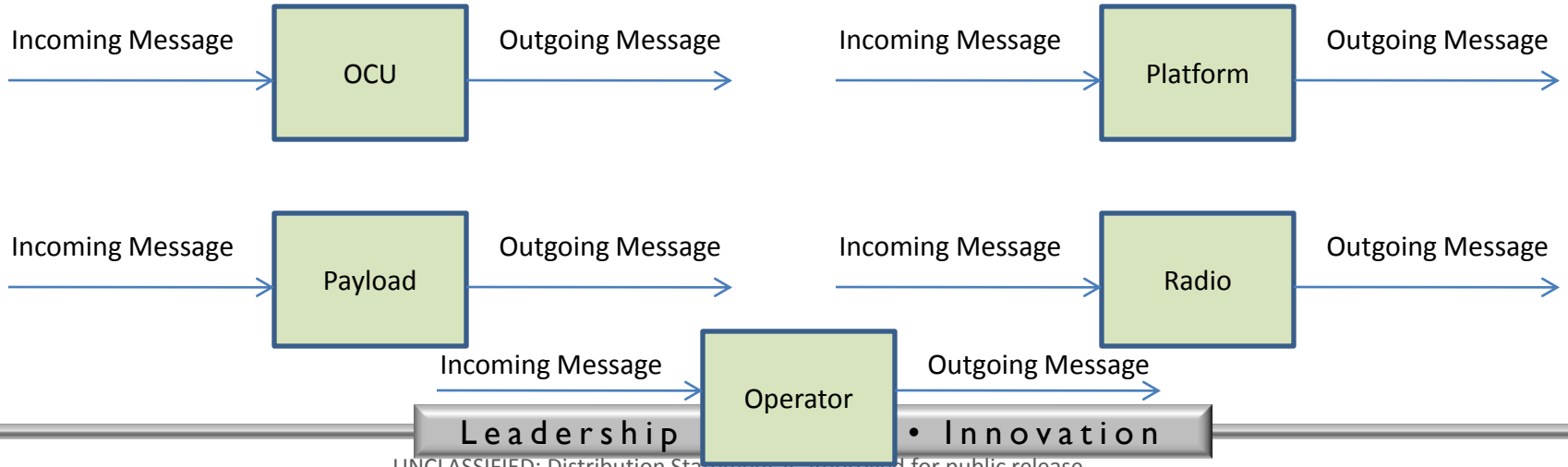
Interoperability Capabilities Implementation Thought Process

- If common messages are used by both the sender and receiver of information, then interoperability can be achieved.
- Each element of a system knows what messages to expect.
- Each element of a system knows what messages to send.



Interoperability Capabilities Implementation Thought Process (cont.)

- We need to specify what the messages are.
- Messages themselves become the interfaces.
- System / subsystem developers know which messages to expect coming in.
- System / subsystem developers know which messages need to be sent by their elements.
- Processes & algorithms within the “black boxes” use the messages & remain proprietary and invisible to others



Interoperability Capabilities Implementation Thought Process (cont.)

- Additional things need to be defined to 1) facilitate proper delivery of messages and 2) enable modularity:
  - Physical interfaces (enabling modularity, as well as adequate throughput of messages & power for messages to flow)
  - Information handling techniques & protocols (enabling reliability of message delivery, flow control, message routing, etc.)
  - Human understandable messages for interaction between the operator and the OCU

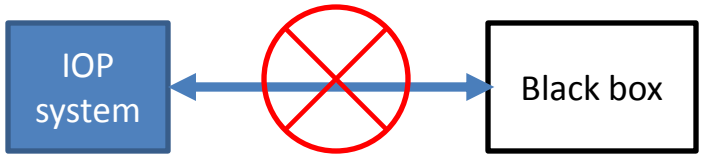
ROBOTIC SYSTEMS JPO

Managing Non-compliant Interfaces in the IOP

Managing Non-Compliant Interfaces - Assumptions

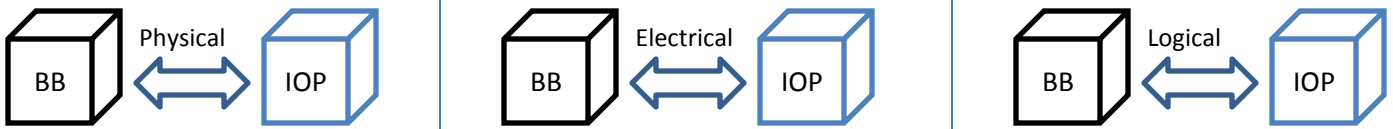
- JAUS terminology is used except where specified
  - i.e. system, sub-system, component, service – all are used in the context of JAUS terminology
- "Payload" – IOP terminology
- "P/E/L" – "physical/electrical/logical"
- "Black box"
  - From Wikipedia: "In science and engineering, a **black box** is a device, system or object which can be viewed solely in terms of its input, output and transfer characteristics without any knowledge of its internal workings, that is, its implementation is "opaque" (black). Almost anything might be referred to as a black box: a transistor, an algorithm, or the human mind."
  - For the purposes of the IOP "the black box…":
    - May or may not be IOP compliant
    - Will have well defined interfaces
    - May or may not be an aggregation of other "black boxes"
    - May or may not host own computational unit
    - May or may not host own communication channel
    - May or may not host own power source
    - …
  - AEODRS calls this a "capability module"

Non-compliant Definition



- A black box that was not standardized by the IOP, and therefore cannot (easily) be added into and work with an IOP profiled system. In other words, one or more of the interfaces are different, be it physical, electrical, or logical, or a combination thereof.
- AEODRS calls this “non-compliance” WRT their systems and sub-systems interfaces.

Simple Determination of Non-compliance



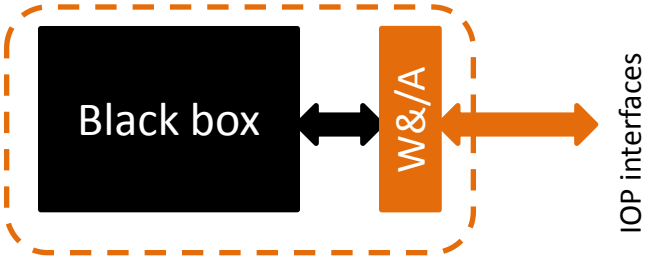
- At its simplest:
  - If it can't be physically attached because the IOP doesn't define the physical interface for it.
  - If it can't be electrically attached because the IOP doesn't define the electrical connector for it.
  - If it can't be logically attached
    - because it doesn't use JAUS
    - because it doesn't use another IOP mandated standard

Options for Interfacing with Non-compliant Black Boxes

ROBOTIC SYSTEMS JPO

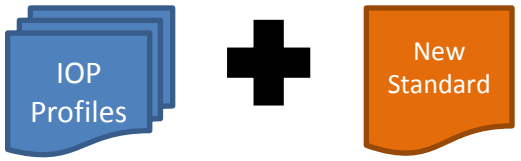
"Wrap and/or Adapt"

- Refers to any means of translation (P/E/L or a combination thereof) between one interface and another
  - i.e. "wrappers" or "adaptors"
- Example:
  - Physical adaptor
  - Electrical adaptor
  - Logical adaptor (software bridge)



"Adoption"

- Adoption refers to the addition of a standard interface to the IOP Profiles
- Examples:
  - Digital video standards, adopted in V0
  - The CCSI for CBRN payloads, adopted in V0
  - "Wrap and/or Adapt" may be necessary for translation between adopted standards

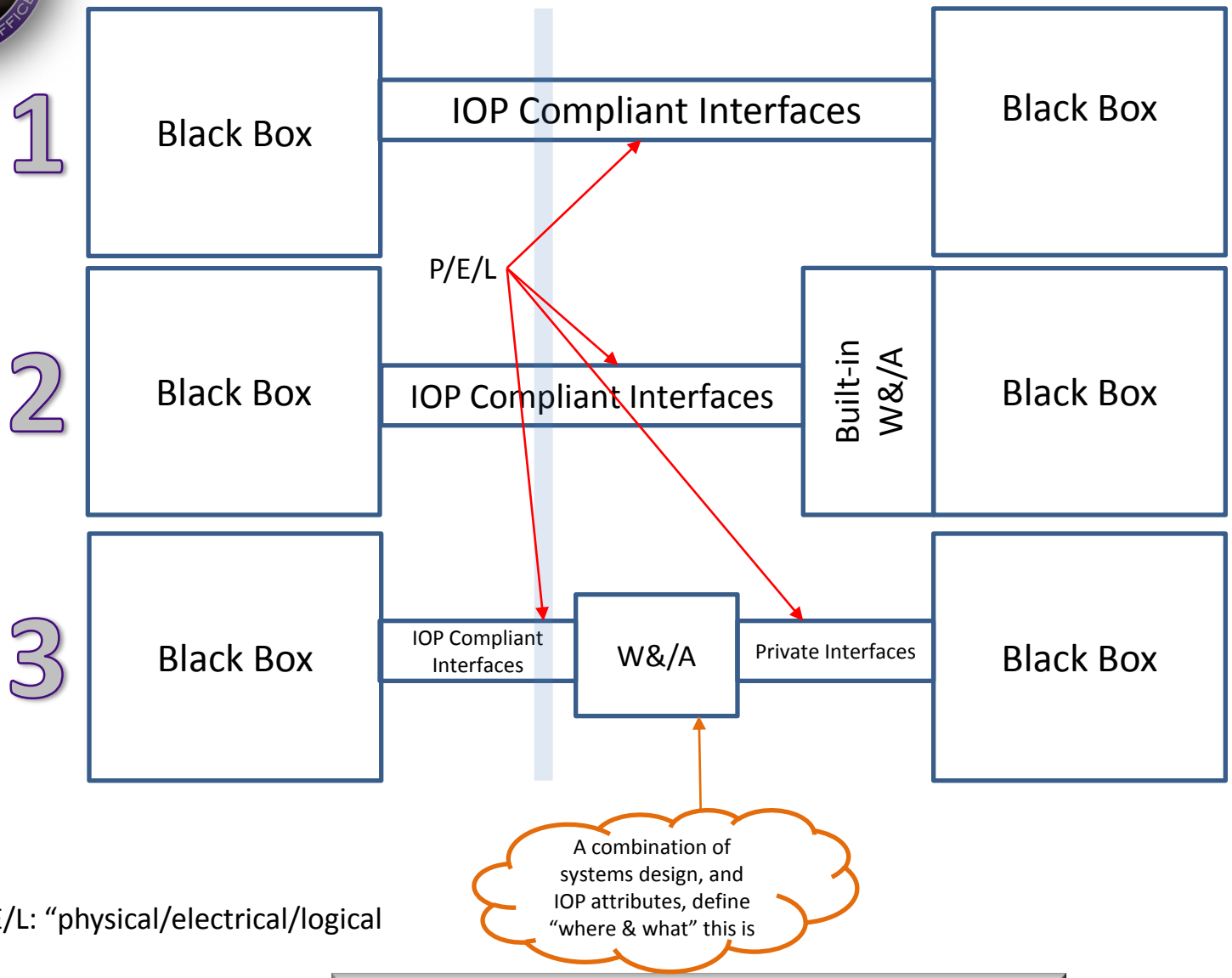


Black Box Examples

Reminder: A black box may or may not be IOP compliant.

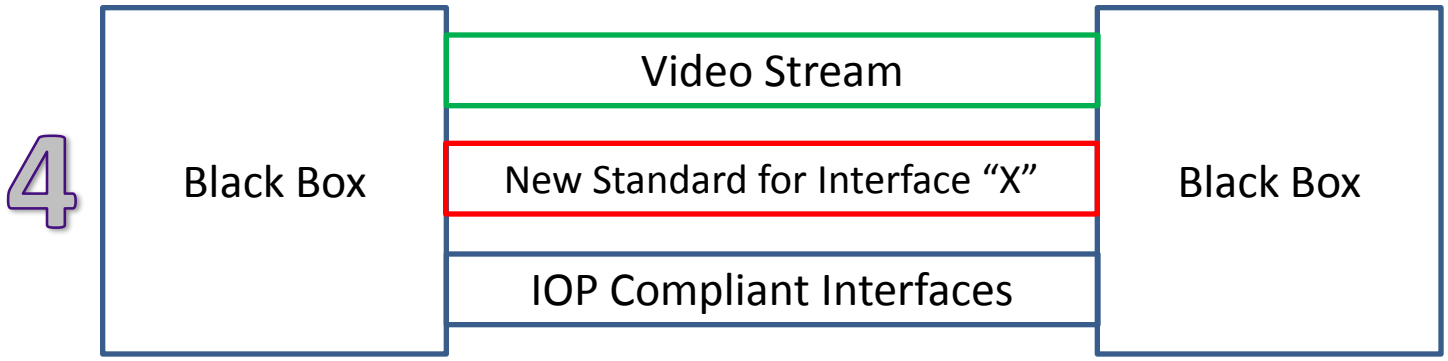
- OCU
- Robotic platform
- Sensor/emitter/actuator
- C2 system
- Database
- GIG
- Human
- Others…

Interfacing Between Black Boxes



P/E/L: "physical/electrical/logical

Interfacing Between Black Boxes: Adoption Example



- This means, there are multiple standards for interfaces.
- Could also mean that somewhere within the system there is/are wrappers and/or adaptors for translation between the standards

All of These Are "Compliant"

All of these are valid configurations, but one may be better than another for a given situation. There is no substitute for "correct" systems design!

- Case 1:
  - Normal IOP compliant black box
- Case 2:
  - Black box with the wrapper built in
  - The "Robot" does not notice a difference, as all messages and interfaces are IOP compliant
- Case 3:
  - An adapter/wrapper was built and inserted between the black boxes
  - The "Robot" does not notice a difference, as all messages and interfaces are IOP compliant
- Case 4:
  - The "X" standard has been "adopted" by the IOP profiles
  - This could imply software adaptors at specific places within the system
  - This could also imply new IOP standard electrical connectors, physical requirements (i.e. new mounting system, threading, etc.) as well as new communications channels – ALL of these would be profiled by the IOP upon introduction of the new standard

IOP Mapping for Program Instantiation

- A business process for determining how to map IOP attributes to an emerging program is a must
  - CDD/CPDs are concerned with overall "high-level" capabilities requirements
  - The IOP, where necessary, will break those "high-level" concepts into "enabling" capabilities
- Ideally this process is transparent
  - i.e. we don't care where in a system you place an IOP compliant black box, because we already defined the IOP attributes associated with its P/E/L interfaces.
- Identification of something that is non-compliant at an early stage allows for
  - Wrap and Adapt
  - Adoption
  - Considerations:
    a) Is it in development? If so can its interfaces be influenced?
    b) Does it have its own standard? Can we adopt the standard?
    c) Can it be adapted without effecting expected system results?
    d) Is it organic to the platform? Example: speedometer on a jeep – the interface may be very different from an already defined speedometer interface through the IOP
    e) Other? TBD
- The entire process is most likely iterative in nature with deliverables and feedback by the IOP-team and the program's design team at different times